

TIROS I METEOROLOGICAL SATELLITE SYSTEM

CCN

FINAL COMPREHENSIVE TECHNICAL REPORT

Volume IV

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CONTENTS

Section	Page
I Introduction	I-1
II Satellite Programming	II-1
A. Summary of Command and Control Equipment Operation	II-1
B. Programming Sequence and Timing	II-1
III Satellite Components	III-1
A. Satellite Receiving Antenna	III-1
1. Design Concepts	III-1
2. Full-Scale Model Impedance Measurements	III-1
3. Failure Isolation	III-3
4. Pattern Measurements on Full-Scale Model	III-3
5. Final Design	III-3
6. Functional Description	III-3
B. Command Receiver	III-3
1. Development	III-3
2. Requirements	III-5
3. Functional Description	III-6
4. Tests	III-8
C. Satellite-Borne Programming Equipment	III-12
1. General	III-12
a. Camera Control Units	III-12
b. Auxiliary Control Unit	III-12
c. Timing and Remove Sequencing Units	III-12
2. Development and Design	III-14
3. Equipment Operation	III-19

CONTENTS (Continued)

Section	Page
a. Camera Control Units	III-19
b. Auxiliary Control Unit	III-21
c. Timing and Remote Sequencing Units	III-21
4. Functional Description	III-25
a. Camera-Control Units	III-25
b. Auxiliary-Control Unit	III-29
5. Acceptance Tests	III-29
6. Auxiliary Circuits	III-34
a. Operation	III-34
b. Tests	III-38
IV Ground Components	IV-1
A. Control Tone Generator	IV-1
1. General	IV-1
2. Functional Description	IV-2
B. Remote Picture Time Set	IV-4
1. General	IV-4
2. Functional Description	IV-4
C. Ground-Based Antennas	IV-7
1. Introduction	IV-7
2. Fort Monmouth and Kaena Point	IV-7
3. Princeton, New Jersey	IV-8
a. General	IV-8
b. Functional Description	IV-10
V Standard Performance-Evaluation Test Philosophy	V-1
A. Requirements	V-1
B. Procedure	V-1
C. Typical Test Results	V-3
VI Operational Modes and Procedures	VI-1
A. Philosophy of Satellite Control	VI-1
B. Operational Modes	VI-2

CONTENTS (Continued)

Section	Page
a. Direct Camera Sequence I	VI-2
b. Direct Camera Sequence II	VI-3
c. Playback and Check-Set Sequence	VI-3
1. Satellite TV Picture-Taking Modes	VI-2
2. Telemetry Control	VI-3
3. Auxiliary Control Functions	VI-3
a. Spin-Up Rocket Selection and Firing	VI-3
b. The Beacon Killer	VI-4
4. Command Programming Control Modes	VI-4
a. The Automatic Mode	VI-4
b. The "Manual Start" Mode	VI-4
c. The "Manual Operate" Mode	VI-4
C. CDA Station Operators	VI-5
1. General	VI-5
2. Proposed CDA Station Crew and Their Duties	VI-5
Appendix A Design of a Low Noise Input Circuit for the Satellite Command Receiver	A-1
Appendix B Derivation of the System Equation for the Phase Monopulse Tracking System	B-1
Appendix C RCA-TIROS Test Specification and Instructions	C-1

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LIST OF ILLUSTRATIONS

Figure No.	Title	Page
1	Programming Diagram, Playback of One Camera System (not followed by Direct Camera Sequence II)	II-3
2	Programming Diagram, Playback of One Camera System (following Direct Camera Sequence II)	II-3
3	Programming Diagram, Playback of Both Cameras Systems (System 1 followed by 2 or 2 followed by 1)	II-4
4	Programming Diagram, Playback of One Camera System (not preceded by Direct Camera Sequence I)	II-4
5	Programming Diagram, Playback of Both Camera Systems (not preceded by Direct Camera Sequence)	II-5
6	Programming Diagram, Direct Camera and Clock Set (no Playback Sequence)	II-5
7	Timing Diagram for Typical Program	II-6
8	Plot of Full-Scale Impedance Measurements (140-Mc Receiving Antenna)	III-2
9	Radiation Pattern 140-Mc Receiving Antenna (Full-Scale Model)	III-4
10	Section of Receiving Antenna Assembly	III-4
11	Satellite Command Receiver, Block Diagram	III-6
12	Satellite Command Receiver, Schematic Diagram	III-41
13	Command Receiver Output Versus R-F Input	III-7
14	Satellite Electronic Clock	III-13

LIST OF ILLUSTRATIONS (Continued)

Figure No.	Title	Page
15	Satellite Camera Control Unit, Schematic Diagram	III-43
16	Satellite Auxiliary Control Unit, Schematic Diagram	III-45
17	Satellite Camera Control Unit, Functional Block Diagram	III-19
18	Timing and Sequencing, Block Diagram	III-23
19	Satellite Command System, Block Diagram	III-26
20	Separation Event Schematic and Rocket Wiring Diagram	III-35
21	Mass Release Time Delay, Schematic Diagram	III-36
22	Squib, Rocket and Timer Test Set, Schematic Diagram	III-36
23	Control Tone Generator, Front View	IV-2
24	Control Tone Generator, Block Diagram	IV-3
25	Control Tone Generator, Schematic Diagram	IV-13
26	Remote Picture Time Set, Front View	IV-5
27	Remote Picture Time Set, Block Diagram	IV-6
28	Remote Picture Time Set, Schematic Diagram	IV-15
29	Princeton Antenna System	IV-9
30	Princeton Antenna Arrangement	IV-10
31	Monopulse Receiving System Functional Diagram	IV-11
32	Test Patterns of Camera Systems I and II, Direct Mode	V-8
33	Test Patterns of Camera Systems I and II, Playback	V-8
34	Amplitude of Sync Pulses Out of TV-FM Demodulator: Deflection; Vertical 0.5v/cm; Horizontal 500 usec/cm	V-9
35	Amplitude of Video Signal Out of TV-FM Demodulator with 1200 ft/candles: Deflection; Vertical 0.5v/cm; Horizontal 500 usecs/cm	V-9

LIST OF ILLUSTRATIONS (Continued)

Figure No.	Title	Page
36	Sun Angle Pulses (10-kc Burst): Deflection; Vertical 0.5 v/cm; Horizontal 50 milliseconds/cm	V-10
37	Horizon Scanner Output (3-kc Tone Burst): Deflection; Vertical 2v/cm; Horizontal 20 uses/cm	V-10
38	Telemetered Data of Camera Systems I and II, Direct Mode	V-11
39	Telemetered Data of Camera Systems I and II, Playback	V-12
A-1	Proposed Receiver Front End, Block Diagram	A-3
A-2	Equivalent I-F Test Circuit	A-3
A-3	Equivalent Circuit Looking into Signal Generator	A-3
A-4	Amplifier Gain-Evaluation Circuit	A-6
A-5	Equivalent Input Circuit for One Receiver	A-6
A-6	Equivalent Input Circuit for Three Receivers	A-6
A-7	Circuit for Filter Noise Figure Determination	A-9
A-8	Alternate Method of Feeding Three Receivers with One Generator	A-13
A-9	Equivalent Independent Input Circuit	A-13
A-10	Actual Receiver Input Circuit	A-16
A-11	Capacitive Transforming Network	A-16
B-1	Monopulse Tracking System, Functional Diagram	B-1

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SECTION I. INTRODUCTION

Programs were sent to the orbiting TIROS I satellite from the selected CDA station by means of amplitude-modulated, 138.06-Mc radio transmission. This supplement lists the modulating frequencies and describes the circuits which generate the modulating frequencies, the antennas which propagate the AM program transmission, the satellite antennas which receive the program signal, and the satellite circuits which demodulate and extract the program from the carrier.

The antenna systems for the ground stations at Kaena Point, Hawaii, and Fort Monmouth, New Jersey, were not supplied by RCA and are therefore described only briefly in this supplement. The antenna system used at the Princeton station was developed by RCA and is discussed in detail.

SECTION I

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SECTION II. SATELLITE PROGRAMMING

A. SUMMARY OF COMMAND AND CONTROL EQUIPMENT OPERATION

The TIROS I satellite's instrumentation and functions can be controlled from any ground-based Command and Data-Acquisition station by means of tone-modulated radio signals.

Four tones (identified in the table of Section IV) enable the camera channels for picture-taking and transmission of pictures to the CDA station; two tones are used to set the electronic clocks; and one tone is used to start the clocks. (An eighth tone is generated, but is used indirectly for control and calibration purposes.)

The command and control equipment is shown in block diagram form in Figure 137 of the main report. This diagram shows the direction of information flow.

The program which is to be sent to the satellite is set up on either one or both of the programmer racks of a Command and Data Acquisition station. When the predetermined start program time is reached, an alarm circuit of the master clock is activated. This closes a relay in the Programmer which turns on the command transmitter carrier and starts the antenna programmer and control tone sequence.

Pulses, produced at 10-second intervals by the master clock, are used to advance a stepping switch located in the Programmer. The stepping switch controls the application of 24 volts to the appropriate relay located on the control tone generator. The relay connects the control tone, which is produced by a tuning-fork-controlled oscillator, to the input of an amplifier which feeds the 600-ohm line to the command transmitter audio input. At the same time, a start signal is sent to the ground tape recorders. This signal also identifies the camera in use and tells whether direct camera or tape playback is called for.

In the case of the clock-set pulses, push-pull gating circuits are used for controlling the bursts of tone and for placing holes in the playback tone into which the clock-set tones are inserted. A four-decade preset counter located on the remote picture time set unit is used to control the number of pulses. These pulses are obtained from a counter decade which receives 1300 cps from a tuning-fork-controlled oscillator and produces twin output pulses (at a 130-pps rate and displaced in time) for setting the vehicle clocks.

B. PROGRAMMING SEQUENCES AND TIMING

Three sequences were used for programming the satellite functions; namely, Direct Camera Sequence I, Direct Camera Sequence II, and the Playback and Clock Set Sequence.

SECTION II

The types of functions which were performed during each of these program sequences are described in Part 2, Section III: The Satellite Command and Control Equipment of the main report. The various combinations of programming sequences, and the timing of the sequences and functions within each sequence are shown in Figures 1 through 6 of this Supplement.

Figure 7 is a timing diagram for a typical satellite program. This diagram shows the commands which are transmitted to the satellite and the responses made by the satellite. The 30-second delay between the commands and responses is due to the required warm-up time of the airborne transmitter and camera.

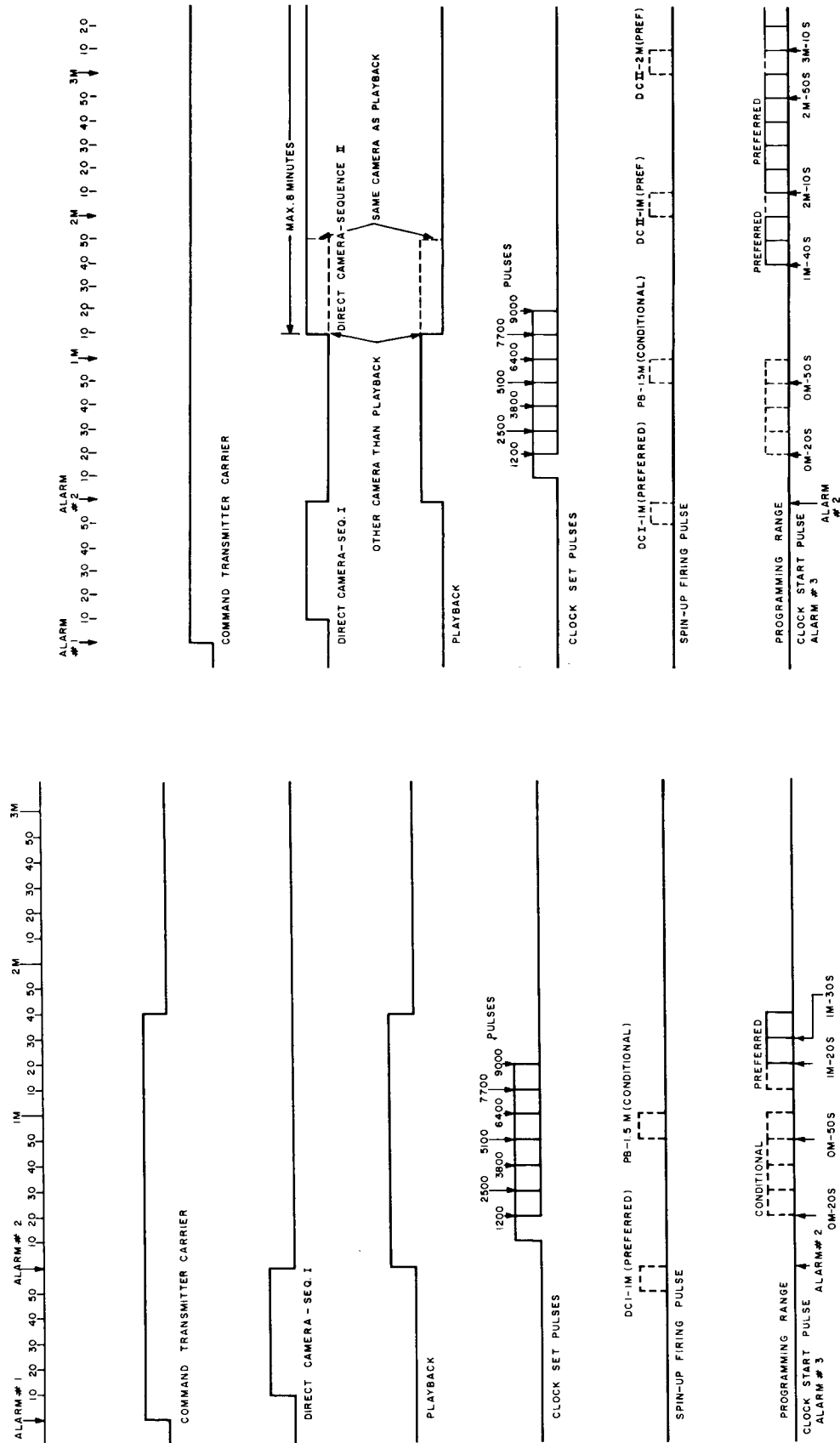


Figure 1. Programming Diagram, Playback of One Camera System
(not followed by Direct Camera Sequence II)

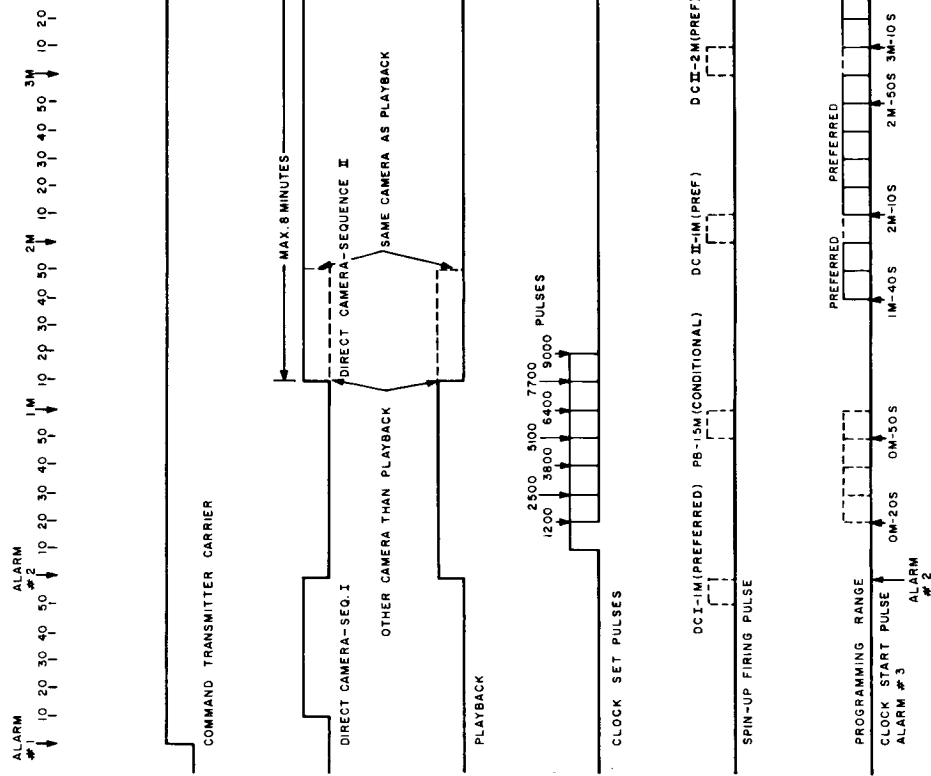


Figure 2. Programming Diagram, Playback of One Camera System
(following Direct Camera Sequence II)

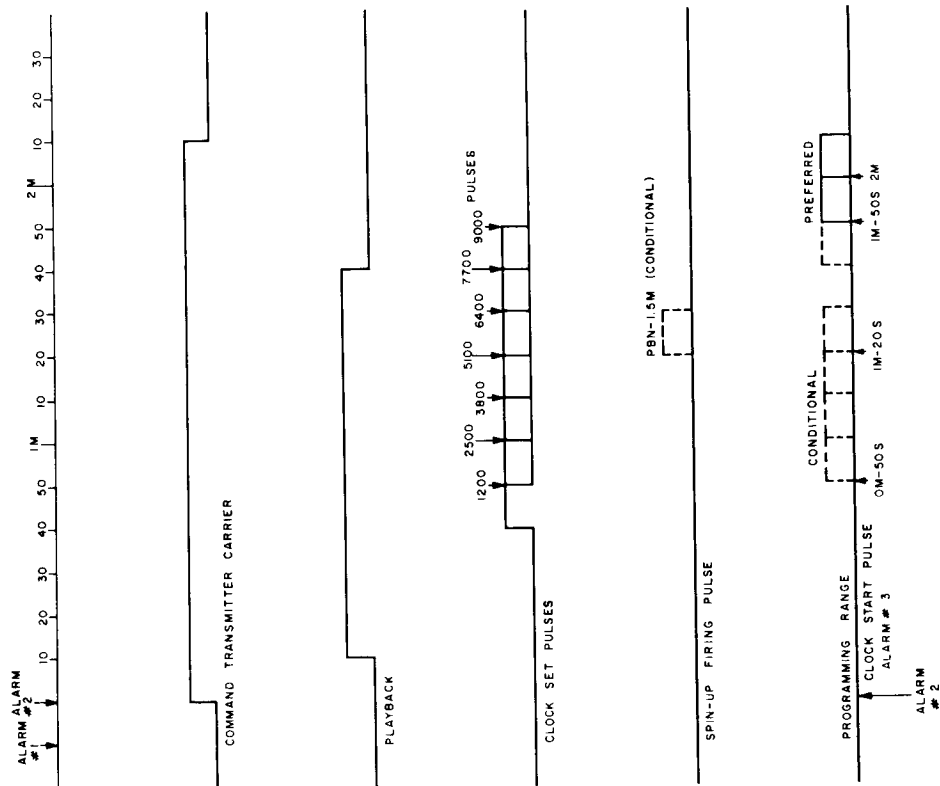


Figure 4. Programming Diagram, Playback of One Camera System (not preceded by Direct Camera Sequence I)

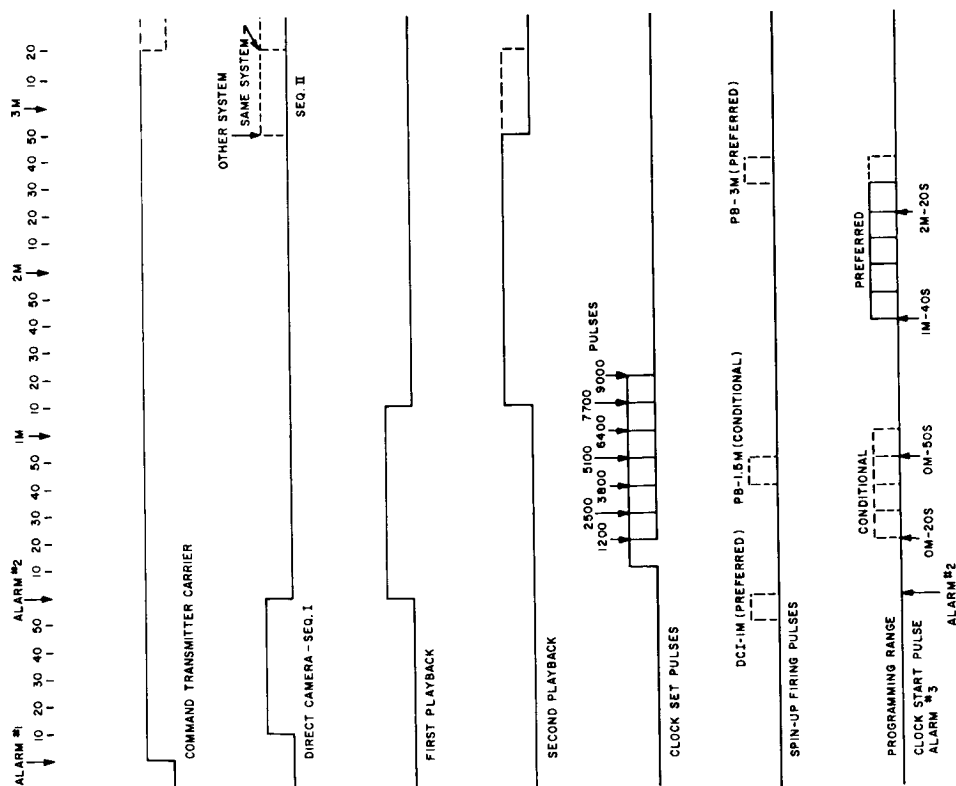


Figure 3. Programming Diagram, Playback of Both Cameras Systems (System 1 followed by 2 or 2 followed by 1)



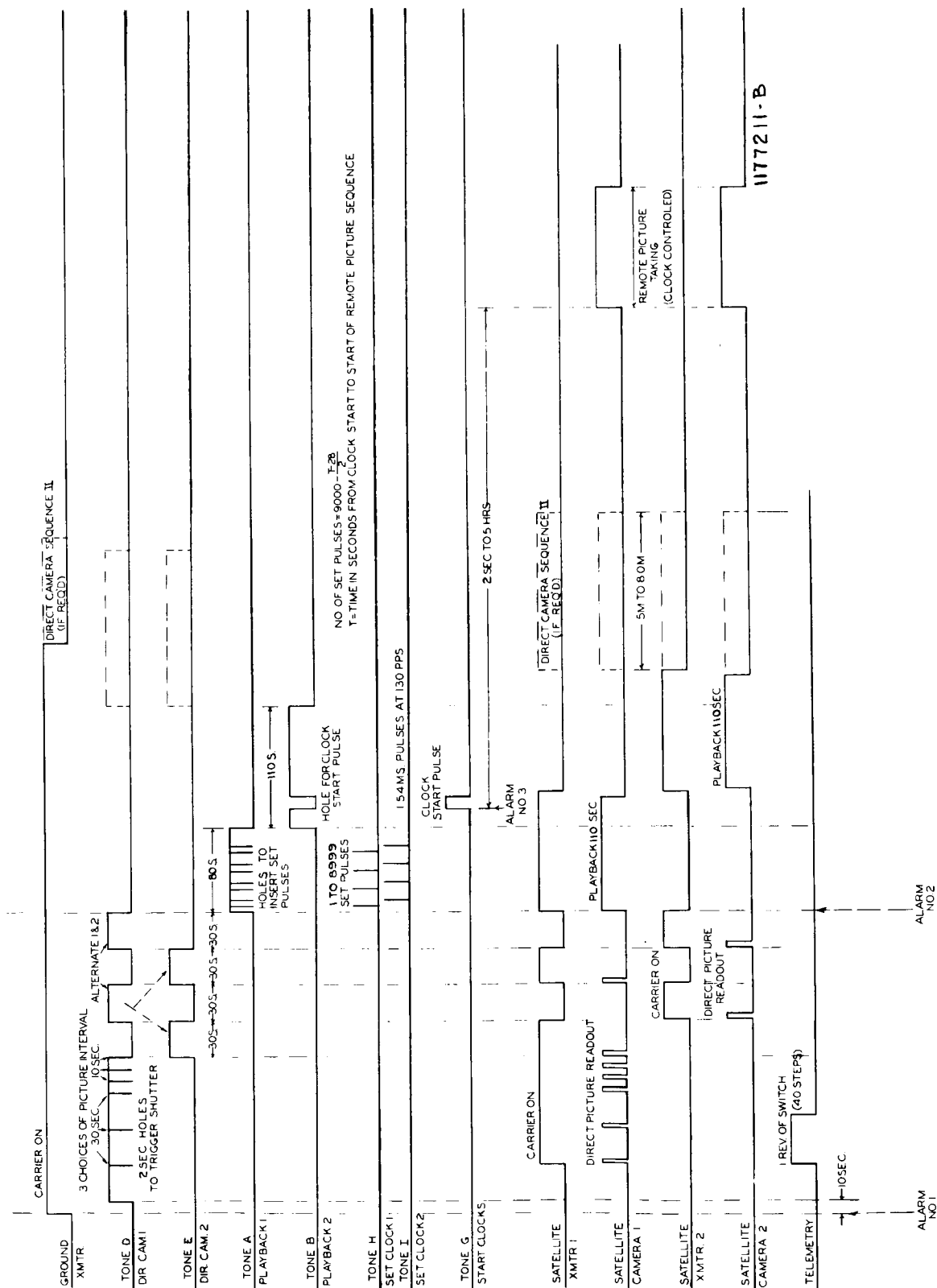


Figure 7. Timing Diagram for Typical Program

SECTION III. SATELLITE COMPONENTS

A. SATELLITE RECEIVING ANTENNA

1. Design Concepts

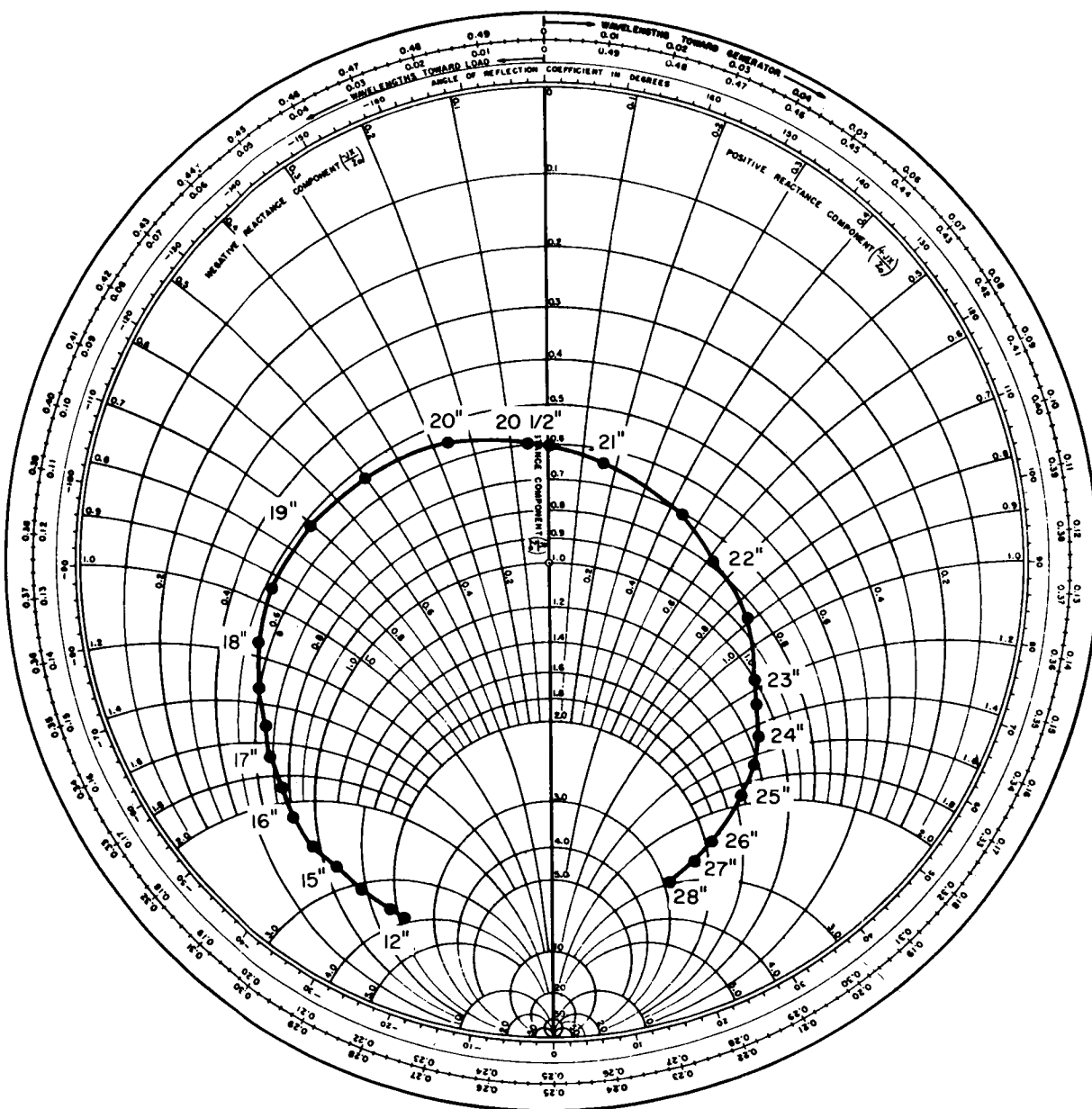
The original concept for a receiving antenna was generally centered around the idea of using the transmitter antenna elements, with a selective filter added to prevent transmitted power from reaching the receiver input. While measuring impedance on the full-scale model, it became apparent that, from the standpoint of obtaining isolation, the neutral plane between the four dipole elements would be the ideal location for a separate receiving antenna because a maximum degree of decoupling existed at this point. If a separate receiving antenna could be located at the center of the top in an axial direction, with connections only to the receivers, the filter requirements could be relaxed considerably.

It was proposed, to the group responsible for the solar cells, that a very fine piano wire, approximately 19 to 21 inches long, be permitted to project out of top center of the satellite. This proposal was rejected on the basis that the sun cell operation would be impaired. At this point, the problem was presented to the group responsible for mechanical design, to determine the practicability of a bottom-mounted receiving antenna which would telescope into the central portion of the satellite until after separation of the third stage rocket, at which time it would spring out in an axial direction from the bottom center. The mechanical design group, after devoting considerable time to the study of this approach, determined that it would be extremely difficult to guarantee sufficient reliability of such a configuration. This approach was then discarded because, although this short piece of piano wire was seemingly insignificant, the operation of the entire satellite was actually reliant upon its proper operation.

At this time, the solar cell group was again approached with the problem, and after some testing in this area, permission was granted to design a receiving antenna which could be mounted in the balance-shaft hole at the top of the satellite.

2. Full-Scale Model Impedance Measurements

Impedance measurements were made on an antenna mounted on a full-scale model. With a length of 20.5 inches, a non-reactive termination of approximately 25 ohms was derived as shown in Figure 8. Two receivers, each having an input impedance of 50 ohms, were to be operated from the one antenna. A match was effected simply by using a half-wave line between the antenna termination and a "T" junction. From the "T" junction, equal length lines went to each receiver.



IMPEDANCE VS ANTENNA LENGTH IN INCHES

339033

Figure 8. Plot of Full-Scale Impedance Measurements (140-Mc Receiving Antenna)

3. Failure Isolation

As a reliability precaution against an effective short circuit appearing at the "T" junction, in case the input circuit of one of the receivers should become open or short circuited, $3/8$ wave lines were used from the "T" junction to each receiver. The $3/8$ wave line was chosen to reflect a pure reactance of 50 ohms across the other receiver line at the center of the "T" junction, if one receiver input should become open or shorted. Some loss would be incurred, but this configuration would cause less loss than other configurations or line lengths. This is an important consideration because there was a 50-50 probability that an input could open or become shorted.

4. Pattern Measurements on Full-Scale Model

The pattern measurements which were made on the receiving antenna, mounted on top of the full-scale model, show only a small variation from the ideal dipole pattern. The actual plot is shown in Figure 9.

5. Final Design

A simple mechanical assembly for supporting and mounting the antenna was fabricated after the electrical design was verified. This assembly is shown in Figure 10. A length of chrome-plate steel piano wire, 0.094 inch in diameter, was clamped (upright) within a conical teflon bushing (4), contained within an aluminum cup-shaped housing (3). A conical nut (5) clamped the bushing against the wire and the bottom of the cup. The lower periphery of the cup is beveled, so that upon insertion through the top of the satellite, it seats on an inversely-beveled bushing at the correct depths. After the assembly is seated, a ring nut (6) is screwed into the satellite aperture to firmly clamp the assembly. The lower terminus of the wire is a UG 290/U coaxial connector (2). The wire "whip" extends just 20.5 inches above the plane of the satellite top when the assembly is installed.

6. Functional Description

The monopole receiving antenna is one-quarter wavelength long and is mounted in a vertical orientation on top of the satellite, in line with the spin axis. The antenna is coupled to both command receivers through a half-wave transmission line, a "T" junction, and two three-eighth wave transmission lines.

B. COMMAND RECEIVER

1. Development

At the start of the satellite program, it had been decided to attempt to use an AM command receiver which had been developed by the Naval Research Labs (NRL) for the Vanguard satellite program. The designers of this receiver indicated that this receiver had been originally designed for a single purpose in accordance with minimum requirements and that there was a possibility that it would require some modification for this

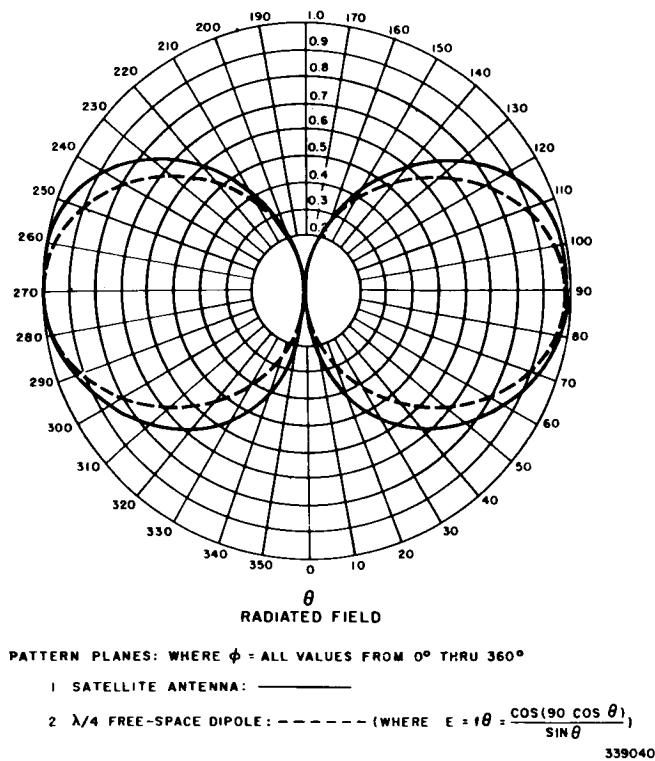


Figure 9. Radiation Pattern 140-Mc Receiving Antenna (Full-Scale Model)

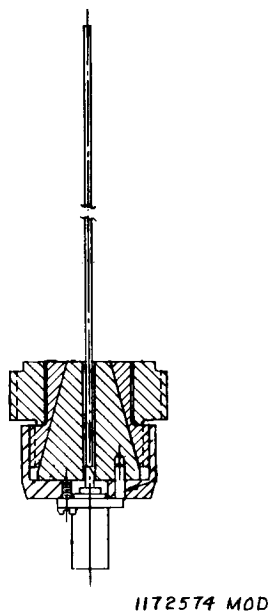


Figure 10. Section of Receiving Antenna Assembly

program. The necessary parts list, schematics and construction drawings were obtained from NRL, a receiver was breadboarded, and an evaluation program was started. Tests indicated that this receiver was subject to many spurious responses because it employed double conversion with a low second intermediate frequency (455 kc). An attempt was made to reduce some of these spurious responses by use of a selective input filter. The filter reduced some of the spurious responses, but it had little effect on a very strong response at 910 kc from the input frequency. Another difficulty encountered with this receiver was a change in the i-f bandwidth and center frequency at different input signal levels. This change was found to have been caused by a change in the transistor loading of the i-f transformers as the AGC changed the operating point of the transistors.

In August 1958, it was decided that a better command receiver could be built by using a different and independent approach to the design. To reduce the number of spurious responses, it was decided to design a command receiver which employed single conversion and an i-f of 20 Mc.

To eliminate the problem of i-f center-frequency change and bandwidth change with variation in input signal levels, a crystal filter was used to provide i-f selectivity; the i-f amplifier tuned circuits were made so that any change in their center frequency or bandwidth would not affect the overall i-f selectivity. The receiver was designed for amplitude-modulation reception because an AM ground-command transmitter had been purchased. Because of the high intermediate frequency selected and the desirability of including r-f amplifiers, germanium transistors were used throughout the command receiver. An analysis of this design is contained in Appendix A of this supplement.

2. Requirements

The basic specifications for the command receivers were as follows:

Power consumption:	-26 v dc at 9 ma
Radio Frequency:	138.06 Mc
Input impedance:	50
Noise figure:	8 to 9 db
I-f bandwidth:	40 kc (6 db down) 100 kc (60 db down)
Output voltage:	1 v rms across 5000 ohms for 80% amplitude-modulation at 1 kc
Spurious responses:	Better than 60 db down
Frequency stability:	± 4 kc
Operating temperature range:	-15°C to + 55°C
Shock:	15 g for 11 milliseconds
Vibration:	25 g rms
Weight:	3/4 pound
Size:	6-1/2 by 4 by 1 inch

3. Functional Description

Figure 11 shows a block diagram of the receiver developed. Two r-f amplifiers in the 130-Mc band were employed to obtain a noise figure of 8 db. Type L5426 MADT transistors were used in the two grounded-emitter r-f amplifiers which provided 12 to 15 db of gain per stage. The output of the r-f amplifiers is fed into the diode mixer and then into a four stage i-f amplifier with a crystal filter inserted between the first and second i-f amplifiers. Separate audio and AGC detectors are used so that each could be independently biased for optimum operation. Three i-f amplifiers are gain-controlled by the AGC feedback voltage.

The schematic diagram of the command receiver is shown in Figure 12.[§] L_1 and C_1 on the input form a 20-Mc i-f rejection trap. T_1 is a bandpass input filter which prevents any out-of-band interfering signals from reaching Q_1 and causing intermodulation distortion. L_2 and C_6 form an image-rejection trap at 40 Mc below the input signal. Image rejection and i-f rejection are down more than 70 db. Q_1 and Q_2 are common emitter r-f amplifiers using high-gain low-noise Type L5426 transistors. A receiver noise figure of 6 to 7 db could have been obtained with these transistors, but circuit losses of 1 to 2 db were presented by the rejection and bandpass filters on the input of the receiver, which increased the overall receiver noise figure 8 to 9 db.

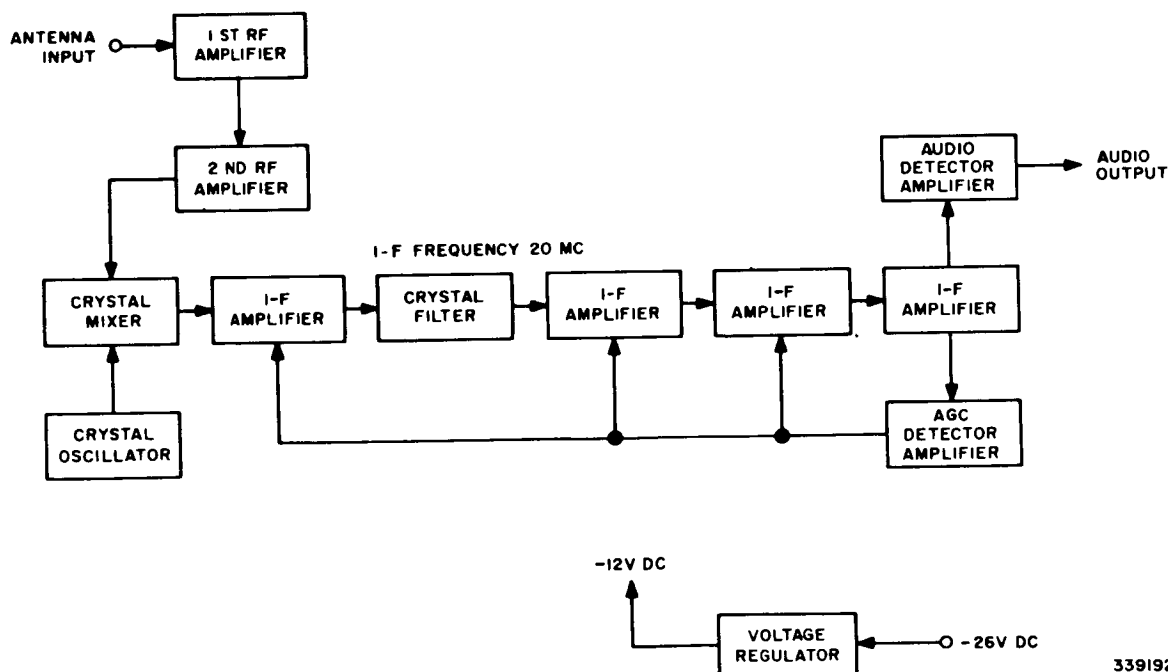


Figure 11. Satellite Command Receiver, Block Diagram

[§] This illustration is printed on a fold-out page located at the rear of Section III.

The output of the r-f amplifiers is mixed with the output of the crystal-controlled oscillator in CR1. The oscillator operates 20 Mc below the input frequency. The oscillator is controlled by a fifth overtone series-resonant quartz crystal. A common base transistor configuration was chosen over the common emitter configuration for the oscillator because it presented a smaller internal phase shift. (Internal transistor phase shift causes the circuit to oscillate at a frequency which is slightly different from the series-resonant frequency of the crystal.)

The i-f amplifier consists of four Type 2N384 transistors used as common emitter amplifiers. A crystal filter is inserted between the first and second i-f amplifiers. This filter has a center frequency of 20 Mc with bandwidth of 40 kc at 6 db down and a bandwidth of 100 kc at 60 db down. Interstage coupling, between transistors, is provided by bandpass transformers, in which the high-impedance winding is tuned. Each i-f amplifier is designed for gain of 20 db when operated with an emitter current of 0.45 ma. The 2N384 transistors were selected for a gain of 20 db in this type of circuit at an emitter current of 0.45 ma.

Automatic gain control is obtained at the i-f amplifier by controlling the emitter current in the first three i-f amplifiers. The signal level in the amplifier is sensed and detected by Q_8 . A negative voltage is produced and amplified by Q_9 ; this voltage is then fed back to the bases of Q_3 , Q_4 and Q_5 to control the emitter current of these transistors. Figure 13 shows the audio output voltage versus the input signal strength of a typical receiver at 20° C and at the temperature extremes that were encountered in the satellite.

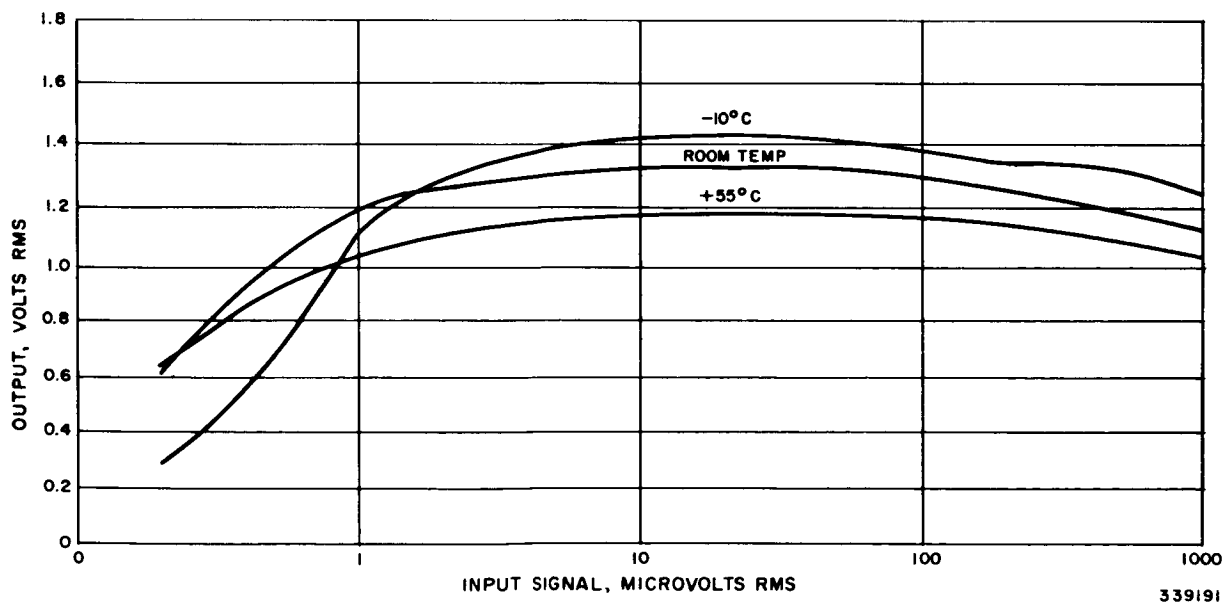


Figure 13. Command Receiver Output Versus R-F Input

SECTION III

The output signal does not vary more than ± 1.5 db for signal inputs of greater than 1 microvolt. The received signal strength of the satellite had been calculated to be a minimum of 5 microvolts and a maximum of 40 microvolts. The receiver has a separate audio detector Q_{11} so that it could be biased to give optimum performance. The base to emitter diode of Q_{10} rectifies the i-f signal and, at the same time, amplifies the modulation that appears on the signal. A voltage regulator, Q_{11} , was incorporated into the receiver so that fluctuations in power-supply voltage do not change the gain of the receiver. The receiver is operable at supply voltages from -18 to -28 vdc with no change in receiver characteristics.

4. Tests

Each receiver was put through complete electrical tests at -10°C , 20°C and $+55^{\circ}\text{C}$. At each of these temperatures, sensitivity, output signal-to-noise ratio, oscillator frequency, mixer current, i-f bandwidth, audio bandwidth and spurious responses were measured. The test data obtained at each of the three temperatures, for a typical receiver are presented on the following pages.

COMMAND RECEIVER ELECTRICAL TESTS AT -10° C

SECTION III

1. Sensitivity and Signal-to-Noise Ratio, 90% 1-kc Modulation

Input (microvolts rms)	Output (volts rms)	Signal-to-Noise Ratio (db)
0.2	0.29	1
0.3	0.45	4.8
0.5	0.67	8.4
0.7	0.88	12
1.0	1.11	15
2.0	1.32	19
4.0	1.4	25
10.0	1.44	32
20.0	1.46	36
40.0	1.43	39
100.0	1.42	40
200.0	1.39	40
400.0	1.39	40
1000.0	1.28	40

2. Noise Output 0.1 rms volt

3. Mixer Current 0.51 ma

4. Supply Current (No Input) 6.3 ma

5. Local Oscillator Frequency 118.05863 Mc

6. I-f Bandwidth

-3 db 31.0 kc Centered 7.5 kc low

-6 db 44.1 kc Centered 3.5 kc low

-60 db 86 kc Centered 6.0 kc low

Maximum Ripple in Pass Band 0 db

7. Audio Bandwidth (Input 1 μ v rms)

-3 db From 111 cps to 8.0 kc

8. Spurious Responses

20 Mc I-f Rejection -87 db

98 Mc Image Rejection -82 db

108 Mc Rejection -98 db

128 Mc Rejection -65 db

SECTION III

COMMAND RECEIVER ELECTRICAL TESTS AT ROOM TEMPERATURE

1. Sensitivity and Signal-to-Noise Ratio, 90% 1-kc Modulation

<u>Input</u> (microvolts rms)	<u>Output</u> (volts rms)	<u>Signal-to-Noise Ratio</u> (db)
0.2	0.62	0
0.3	0.8	3.3
0.5	1.03	7.2
0.7	1.12	10.5
1.0	1.19	13.5
2.0	1.28	19
4.0	1.32	25
10.0	1.35	32.5
20.0	1.35	38
40.0	1.35	42
100.0	1.34	45.5
200.0	1.3	46.5
400.0	1.25	46
1000.0	1.14	46

2. Noise Output 0.34 rms volts

3. Mixer Current 1.02 ma

4. Supply Current (No Input) 7.9 ma

5. Local Oscillator Frequency 118.05847 Mc

6. I-f Bandwidth

-3 db 29.7 kc

Centered 7.3 kc low

-6 db 42.1 kc

Centered 4.4 kc low

-60 db 87 kc

Centered 5.5 kc low

Maximum Ripple in Pass Band 0 db

7. Audio Bandwidth (Input to 1 μ v rms)

-3 db from 12.4 cps to 8.5 kc

8. Spurious Responses

20 Mc I-f Rejection -88 db

98 Mc Image Rejection -79 db

108 Mc Rejection -105 db

128 Mc Rejection -70 db

COMMAND RECEIVER ELECTRICAL TESTS AT +55° C

1. Sensitivity and Signal-to-Noise Ratio, 90% 1-kc Modulation

<u>Input</u> <u>(microvolts rms)</u>	<u>Output</u> <u>(volts rms)</u>	<u>Signal-to-Noise Ratio</u> <u>(db)</u>
0.2	0.64	-1.1
0.3	0.76	2.2
0.5	0.9	6.7
0.7	0.98	9.2
1.0	1.05	13
2.0	1.1	18.5
4.0	1.15	24
10.0	1.17	32
20.0	1.17	37
40.0	1.18	43.5
100.0	1.18	49
200.0	1.17	53
400.0	1.14	54
1000.0	1.08	54

2. Noise Output 0.39 rms volt

3. Mixer Current 1.2 ma

4. Supply Current (No Input) 9.0 ma

5. Local Oscillator Frequency 118.05734 Mc

6. I-f Bandwidth

-3 db 39.0 kc

Centered 10.5 kc low

-6 db 43.4 kc

Centered 5.1 kc low

-60 db 89 kc

Centered 8.5 kc low

Maximum Ripple in Pass Band 0 db

7. Audio Bandwidth (Input 1 μ v rms)

-3 db from 136 cps to 10.0 kc

8. Spurious Responses

20 Mc I-f Rejection -88 db

98 Mc Image Rejection -80 db

108 Mc Rejection -106 db

128 Mc Rejection -87 db

C. SATELLITE-BORNE PROGRAMMING EQUIPMENT

1. General

The various satellite subsystems, which are subject to command from the ground stations, are controlled and sequenced by the programming and control system. Ground-command tone signals are applied from the outputs of the command receivers, through appropriate tone bandpass filters to the various control circuits on a time-shared basis. The system consists of two function (camera) control units, one auxiliary equipment control unit, and two timing and remote-sequencing units. The two separate camera control and timing and remote-sequencing units are provided to permit separate control of the wide- and narrow-angle cameras. The two command receivers also served as part of the programming and control system although they are described elsewhere in this classified supplement.

a. Camera Control Units

The camera control units provided the following control functions:

1. direct picture read-out,
2. stored picture read-out,
3. clock elapsed-time set, and
4. clock start.

b. Auxiliary Control Unit

The auxiliary control unit provided the following control functions:

1. beacon transmitter control,
2. telemetry start/stop control, and
3. spin-up rocket control.

In addition, the auxiliary control unit monitored the output of the horizon scanner and converted this output into the necessary pulse form for transmission to the ground stations.

c. Timing and Remote Sequencing Units

The timing and remote sequencing units (Figure 14) consist of an electronic clock and its associated set and start circuits which perform the following functions:

1. storage of commands and sequencing of cameras and recorders,
2. provides vertical and horizontal sync to the cameras,
3. provides sync to the tape-recorder power supply, and
4. performs the necessary switching for sequencing.

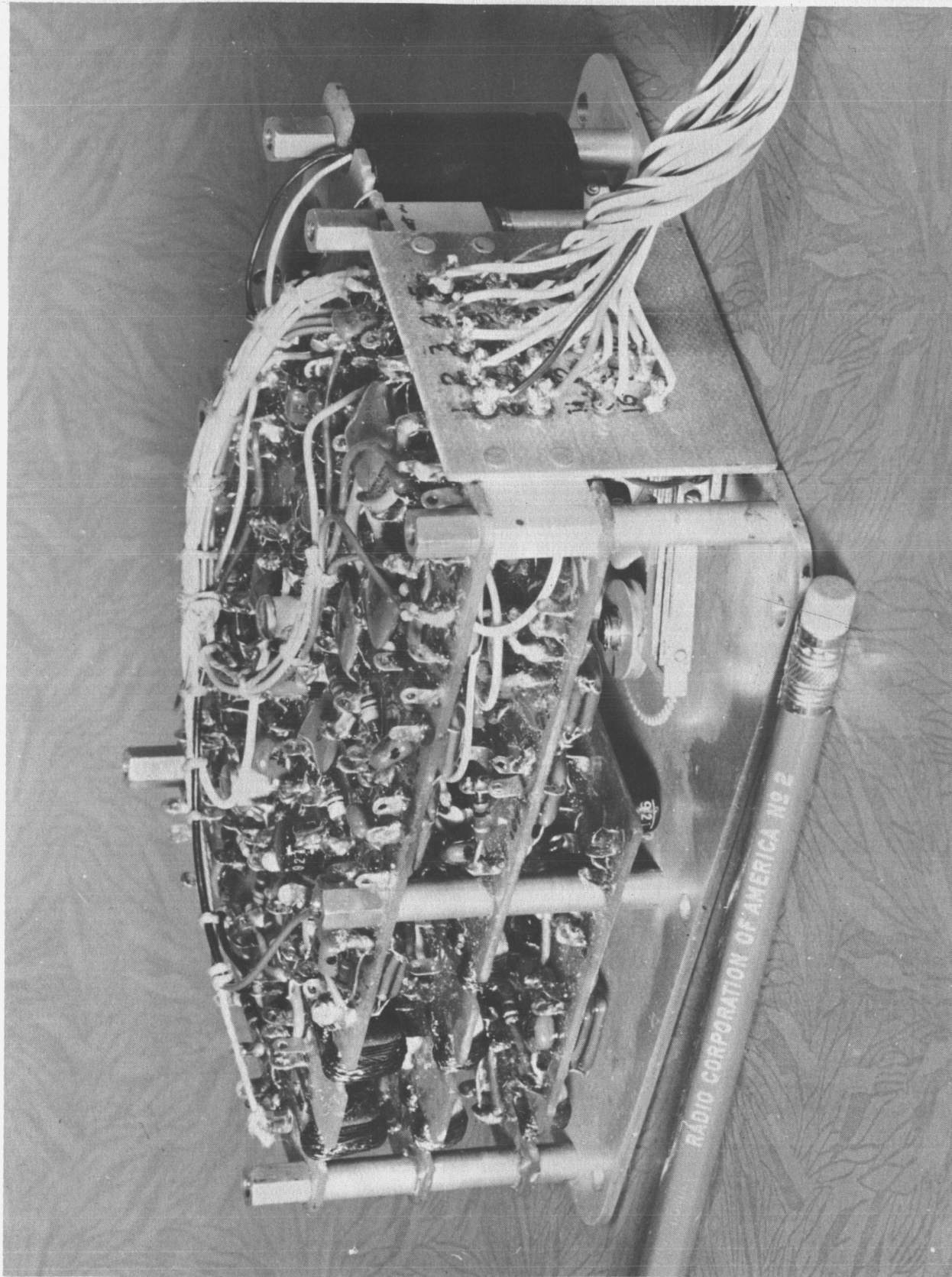


Figure 14. Satellite Electronic Clock

2. Development and Design

a. Camera Control and Auxiliary Control Unit

(1) Basic Requirements

The development of the programming and control (command) system, started in December of 1958. At this time, the TV cameras, recorders and their associated electronics, as well as the communications components, were in the advanced design phases. The basic mission of the satellite was generally decided so that the command sequences, timing, etc., could be established. Because of the extremely short development time allotted, it was decided to tailor the command system to the TIROS mission by using the simplest most straightforward techniques to achieve maximum reliability. The primary considerations for the command system were as follows:

- (a) Immunity from spurious interrogation should be provided.
- (b) Anti-jam provisions were not required.
- (c) Ground programming errors would not cause damage to the satellite.
- (d) High-speed command was not required.

These factors led to a choice of a simple analog tone-command system rather than the more complex and flexible digital systems. However, by time-sharing the tones, the number of control functions obtained was greater than the total number of tones used.

Prior to the selection of an audio-tone system, studies were made using free space attenuation on the command signal from ground to receiver, and propagation data was compiled for a satellite at a 400 nautical-mile elevation with a maximum slant range of 1435 nautical miles (5° above horizon). These studies indicated that by using selective filters (i.e., 1 kc maximum bandwidth) a 45-db tone-to-noise ratio could be achieved. A tone detector circuit had been developed at this time which could operate at a tone-to-noise ratio of as poor as 12 db so that the signal available from the receiver was more than adequate for error free command system operation. These propagation characteristics were later verified by actual signal strength data received. It was amply demonstrated that the command system was quite positive, and very little difficulty was experienced in maintaining smooth control of the satellite.

(2) Considerations for Minimizing Power Drain

Because the command system, of necessity, had to be enabled 100% of the time, it was important to select circuits for their minimum power-drain capabilities. In some cases, during contact with the satellite, certain control read-out-pulses were only required for a small fraction of the total contact time. This suggested using circuits which would consume power only when supplying an output and would normally be off between outputs. A satisfactory solution to this requirement was to use complementary transistors, such as flip-flops, for switching circuits because, when the flip-flop was in the off condition, both transistors would be off, thereby consuming no power. When the flip-flop was on, both transistors would be on, but because the

flip-flop on time would be short, the total power would be negligible. These techniques were used extensively throughout the design of the command circuits. The only circuit which required significant power, was the audio amplifier which followed the command receiver. This circuit consumed about 4 milliamperes constantly.

To provide immunity to spurious interrogations, all tone detectors were normally cut-off, except when the satellite was commanded. The satellite was virtually immune to spurious interrogations because a 28-second delay time was required to energize the TV transmitter when the main control portions of the satellite were enabled. This 28-second delay was integrated with the time required to pre-heat the filaments of TV transmitter, so that actually, no additional time was required for this function. With this 28-second delay required to enable the satellite, it was very unlikely that a spurious radio or noise signal would have the proper r-f and audio-frequency components for a sufficient time to cause any difficulty. Of course, once the satellite was enabled, interfering signals could have caused difficulties, and some difficulties were experienced in generating errors in count settings to the clocks. This problem will be discussed in subsequent paragraphs.

In the main command system, there was no known occurrence of a spurious transmission turning on a camera or reading out remote pictures observed. During the system development, there was no requirement for anti-jamming in the command system. However, a study was made to determine the immunity of the system to foreign signals.* It was believed that, because the satellite was an experimental scientific mission, jamming would not be a problem. No known case of intentional jamming was observed during the active life of the satellite.

Several problems were encountered during the breadboard phase of the command circuit development. The major problems encountered were: spurious clock set pulses which were caused by other commands, tone detector transistor failures, and the 28-second and 26-second delays drifting with temperature.

To prevent spurious clock set and clock start pulses from being generated while the satellite was between ground station commands, it was found to be necessary to disable the power from the set and start one-shot circuits. This means that when interrogated, these circuits would have to be energized without generating spurious pulses. This is a rather difficult requirement for a one-shot. The problem was solved by energizing half the one-shots continuously (Q_{12} and Q_6) and then switching on Q_{13} and Q_9 when required. See the Camera Control Unit Schematic diagram, Figure 15.‡
*This scheme permitted the speed-up capacitors C_{26} and C_3 to charge to a voltage equal to that when Q_{13} and Q_9 were switched on. Hence, when these circuits were energized, no charges were disturbed on any of the capacitors, and therefore no spurious output pulse was generated.

* RCA TIROS TM210-12. Immunity of the TIROS I Satellite Control System Against Response to Foreign Signals.

‡ This illustration is printed on a fold-out page, located at the rear of Section III.

SECTION III

Unfortunately, however, the switching voltage contained noise which was caused by the characteristic bounce of a relay contact. This noise voltage did produce spurious pulses on occasions despite the careful design efforts. To prevent these noise pulses, gate transistor Q_{30} was provided with a time constant (R65-C28) to remove these voltage pulses. This prevented the spurious switching outputs from the start and set circuits.

Several failures occurred in transistors Q_7 and Q_8 during development. These failures were traced to the charging current in C_4 and C_5 which was found to be excessive. This current exceeded the ratings of the detector transistor and eventually caused it to fail. This problem was solved by including R105 and R106 to limit the maximum current to a safe value.

During the development of the 28-second transmitter delay circuit (see the Auxiliary Control Unit schematic diagram, Figure 16[§]) which consists of Q_{24} , Q_{18} and Q_{22} , a 2N329-A transistor was used for Q_{24} and no temperature compensation (thermistor TR2) was used. Delay time variation, after the nominal 28 seconds was set, was ± 0.5 seconds over a temperature range of -10°C to $+60^\circ\text{C}$. This was well within the requirements of the system for ± 1 second. However, when the breadboard was reproduced in the first engineering model, delay times varied as much as ± 5 seconds over the temperature range, depending on the transistor used. The trouble was caused by the shift in the d-c gain of the silicon transistor with temperature. Because the effective value of capacitor C_9 in this circuit depends on the d-c gain of Q_{24} , the time constant varied with temperature.

By selecting transistors from batches (the HA7528 was used because it was more readily available) and using thermistors with external trimming resistors, the time variation was brought within specification limits. The same temperature problems were encountered in the development of the 26-second off delay circuit. These problems were corrected by the same compensation methods.

(3) *Integration Into Satellite*

Because the command system in effect ties all the subsystems of the satellite together, it was vitally important that all interface problems be carefully eliminated. Relatively few interface problems between the command system and other subsystems were encountered. This is particularly noteworthy because the satellite system was fully tested for the first time after having bypassed the full satellite breadboard phase in order to save time.

The problems which did arise during integration were as follows:

- (a) Human errors during test
- (b) Synchronizing direct-camera shutter pulse with clock vertical sync

[§] This illustration is printed on a fold-out page, located at the rear of Section III.

- (c) Rise-time problem on shutter pulse
- (d) Loading of clock-set circuit
- (e) Noise from camera shutter pulse
- (f) Ambiguity on alternating camera sequence
- (g) Record-motor power interlock during playback

The most serious problem encountered in integrating the command system into the satellite was caused by human error. These errors for the most part were caused by shorting the outputs of the command system to ground, during tests, with probes from oscilloscopes and voltmeters. The satellite was particularly vulnerable to this because of the closeness of terminals on boxes and poor accessibility to test points.

Because the command system is, by nature, a power source for all other subsystems, short circuits were particularly damaging, especially to relay contacts. About six relays had to be replaced because of frozen contacts which resulted from accidental shorts. These occurrences did decrease as the system checkout procedures became more refined. A solution to this problem for future systems, is to use plugs on all boxes, and to use special extension cables with test points for trouble shooting. Problem (b) was actually solved during the breadboard stage.

Because the phase of the vertical sync generated in the clock is unknown from the ground, and because it was required that the camera shutter operate during blanking or at the start of vertical sync, it was necessary that ground command for a picture be related to the vertical sync. This was accomplished by enabling gates (G-21, G-22) from ground command. The gate would then wait for the next clock sync signal to actually generate the picture shutter readout cycle. Besides the gate, two flip-flops and a Schmitt-trigger circuit were required to accomplish this.

The output of camera control unit CC1, terminal 9, feeds the shutter flip-flop as well as the modulator in the R-3 box of the recorder electronics. Decoupling circuits with large R-C time constant were used to load the shutter and two second command. These decoupling circuits deteriorated the rise time so that the shutter drive flip-flop did not trigger. This was solved by feeding the shutter flip-flop from a separate source (Q₂₁ through pin 21). The rise time at this point is unaffected by recorder electronics circuit loading effects.

The shutter solenoid receives power from a pair of special brushes which ride on a track. Early shutters presented alignment and other mechanical difficulties which caused the brushes to bounce and create large transient spikes on the regulated power line. This noise fed back to FF 12 and FF 22 and turned them off at approximately 50 milliseconds rather than 2 seconds after a picture readout began. This resulted in a corresponding shortening of the TV subcarrier. This problem disappeared when improved shutters were developed and installed.

SECTION III

b. Timing and Remote Sequencing Units

During 1958 there was considerable question as to the number and function of the clocks and cameras to be carried aboard the satellite. Considerable study and time were being devoted to the development of a camera scheme with which the clocks would be required to operate. Electromechanical clocks had been developed and delivered by the General Time Corporation for use on the JUNOMET project, but as the camera studies progressed, it became apparent that different clocks would be required to meet the requirements imposed by the camera changes, because of the many system changes that resulted in TIROS I. These changes resulted in many design and delivery delays.

When the first clocks which were delivered were evaluated, it became evident that there were serious circuit troubles. In one or two of the clocks, transistor breakdowns occurred; and thermal instabilities were evident in at least 50 to 70 percent of the clocks. An immediate program was initiated to check the clocks and study their behavior. As a result of this concerted effort, many design weaknesses were detected. In each problem area a solution was found and worked out in cooperation with the General Time Corporation. The transistor breakdowns were traced to the core kickback voltage which added to the supply voltage. The transistors used in the earliest germanium clocks were rated at 25 volts collector-to-emitter. Under certain conditions, the V_{ce} would reach 28 volts, and some transistors broke down under this stress. As soon as this problem was isolated, two immediate steps were taken; higher voltage transistors were used in all new clocks, and the previously produced clocks were protected by adding Zener diode crowbars across the transistors. The Zener diodes were selected to breakdown before the transistor junction ruptured. These steps eliminated the transistor breakdowns.

Thermal instabilities were detected and presented the difficult task of determining where and why the effect was taking place because the problem would appear only during thermal-vacuum tests. Eventually the instability was found to be caused by the peculiarities of heat transfer in a vacuum. It has since been determined that one INCREMAG core would heat up at a faster rate than another core in the divider chain. Because the core hysteresis loops changed with temperature the counter would change count. Circuit instabilities in the germanium transistors (thermal variations in V_{be} and I_{co}) accentuated the problem. Again, solutions were found and applied to the circuits. The cores were thermally linked together with an aluminum-loaded epoxy, conformal coating and the characteristics of each core and transistor combination were custom trimmed after the entire clock had been baked at $+80^{\circ}\text{C}$. for several days. These changes were followed by extensive vacuum checks. After these changes were made, only three out of 168 cores failed, and in these three cases, all were marginal failures.

The direct picture vertical counters, each of which has four cores, developed no troubles during the tests. This performance was attributed to the silicon transistors which were used in the circuit.

In addition to the electrical and environmental problems, many workmanship problems were encountered. Considerable time and effort was expended in tracing and

correcting cold-solder joints which caused intermittent circuits. As a result, the quality control requirements were increased and failures decreased to a minimum. All of the clocks in which silicon transistors were used were made under very rigid quality control conditions, and then carefully inspected by RCA reliability and quality control groups.

3. Equipment Operation

a. Camera Control Units

The two camera control units contain the circuit logic and control functions necessary to operate the two TV picture systems in both the remote and direct picture modes of operation. These are shown in the functional block diagram, Figure 17. The interrelationships of the various circuit functions during the sequential phase of each mode are somewhat complex but the following description is presented to show the basic sequences.

(1) Remote Picture Mode

During a satellite pass over a CDA ground station, the clocks are programmed by transmitting the proper number of set pulses to the satellite. After a predetermined time interval has been programmed into the clocks, the start pulse is transmitted. The time of transmission of this start pulse, in conjunction with the programmed time intervals in the clocks, determine the orbital position of the satellite at which the clock will alarm and initiate the remote picture taking cycle.

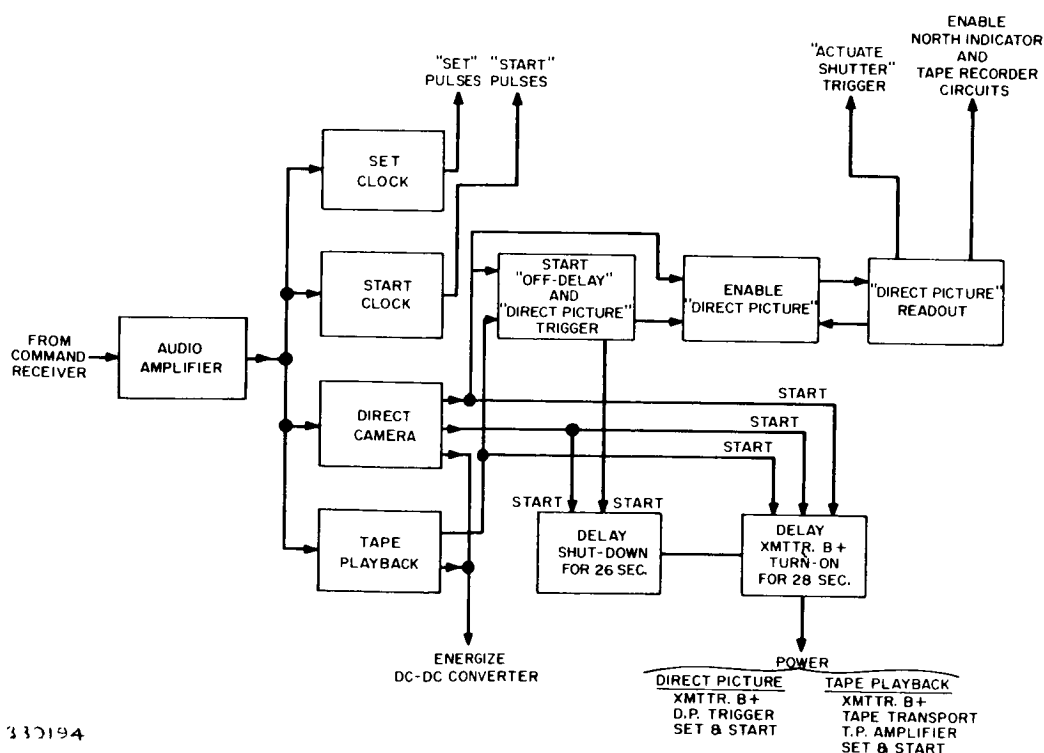


Figure 17. Satellite Camera Control Unit, Functional Block Diagram

The active functional circuits in the camera-control units, during the remote picture mode of operation, include the: (a) audio amplifier, which is in operation during all modes of satellite operation, (b) the clock-set circuitry, and (c) the clock-start circuitry.

- (a) The audio-amplifier circuits receive the various command signals from the command receiver, in the form of tone bursts at different frequencies and of differing duration, amplify these signals and develop the proper pulse forms for detection by the appropriate bandpass filter.
- (b) The clock set circuitry detects the set pulses received from the audio amplifier and supplies the clock unit with a set pulse of the same repetition rate (130 pps) but reshaped to provide appropriate rise and fall time.
- (c) The clock start circuits detect the appropriate command signal from the audio amplifier and supply the clock with a start pulse of increased amplitude (-23 V) and approximately an eight-second duration.

(2) Tape-Playback

The playback mode of operation, during which the previously recorded remote picture data is transmitted to the ground, is initiated during a satellite pass over the ground station when a command signal of the proper frequency is transmitted to the satellite. This playback signal is blanked intermittently in order to permit transmission of clock-set pulses on a time-sharing basis during the time interval when the satellite is over the ground station. This blanking is of a sufficiently short duration that the off-delay start circuitry, which normally becomes operative when the tone is turned off, is not affected.

Receipt of the tape playback tone, (at a time designated t_o (PB)) energizes the dc-dc converter (which supplies power to the transmitter filaments). At time t_o (PB) + 28 seconds, the transmitter B+ delay circuit closes a relay which supplies B+ power to the transmitter, the recorder, and the playback amplifier. The recorder then goes through its playback cycle, shutting itself off upon completion of the cycle. When the playback tone is removed, the off-delay start circuitry energizes the 26-second off delay and, unless either a playback or direct camera tone is received in the interim, the playback equipment is de-energized 26 seconds later.

(3) Direct Camera

The direct camera mode of operation is employed when the satellite is within communication range of the ground stations and the video data may be transmitted directly without the necessity of the record or playback functions. Upon receipt of the direct camera tone from the ground station (at time t_o (DC)) the camera and the dc-dc converter, which supplies filament power to the transmitter and the camera preamplifier, are energized. At time t_o (DC) + 28 seconds after the transmitter and camera circuits have been warmed, the transmitter B+ delay circuit closes a relay

which supplies B+ power to the transmitter and camera circuit and enables the shutter and the clock set and clock start circuits.

Upon removal of the direct camera tone, operation of the direct picture enable circuit is initiated. With this circuit in operation, the next camera sync pulse (at 0.5 pps from the clock) causes a shutter-actuating trigger pulse to occur. This pulse also initiates a readout signal, of a two-second duration, which is applied to the north indicator system and to the recorder package. The direct camera tone, having been removed to start the direct picture enabling circuit, energizes the off-delay start circuit which energizes the 26-second off delay. Unless a playback tone or another direct camera tone is received in the interim, the direct-camera equipment will be completely de-energized after a 26-second delay.

b. Auxiliary Control Unit

The auxiliary control unit contains the necessary tone filtering, logic circuitry and switching elements to perform the following satellite control functions:

- a. Turn the beacon transmitters off and on upon proper ground command.
- b. Start and stop the satellite telemetry equipment during a satellite pass over the ground station.
- c. Provide a control pulse to initiate readout of the I-R experiment during a satellite pass over the ground station. (This function was provided for but not used.)
- d. Provide command signals to the spin-up rocket switch upon proper ground command.
- e. Monitor the output of the I-R horizon scanner and convert this output into the necessary pulse form for transmission to the ground station.

(1) Beacon Control

The beacon killer circuit was provided to permit the beacon transmitters to be disabled during certain orbits or at the end of the satellite's useful life. The circuit de-energizes the beacon transmitters upon receipt of a clock start pulse of at least 20 seconds duration. Power could later be restored to the beacon transmitters by ground transmission of either a tape-playback or a direct-picture command tone.

(2) Telemetry Control

During either a tape-playback or direct-picture mode of operation, the telemetry control was enabled. This control circuitry initiated and terminated the operation of the telemetry selector switch, which rotated through one cycle, sampling all telemetered data in the satellite. The monitored data was applied to the two sub-carrier oscillators and transmitted to the ground by the beacon transmitters.

SECTION III

(3) *I-R Heat-Mapping Subsystem Readout*

Although not actually used, provision was included to enable an I-R start circuit during the tape-playback mode of satellite operation. This circuit was capable of supplying an initiating signal to the I-R subsystem in the form of a 24-volt, negative-going pulse of approximately 50-milliseconds duration.

(4) *Spin-Up Rocket Command*

Monitored data indicated that the rotational speed of the satellite had dropped below a specified rate; it was necessary to fire a pair of spin-up rockets to increase this rate. The ignition voltage was applied through a rotary selector switch. This selector switch was driven by the spin-up rocket control circuitry which, upon receiving a ground-command 3-kc tone for 6 seconds, advances the switch one position to fire one pair of spin-up rockets.

c. *Timing and Remote Sequencing Units*

The timing and remote sequencing units were manufactured by the General Time Corporation and were designed and tested to meet the requirements of satellite operation. (See RCA-AED Technical Memos 210-10 and 210-13.) Each unit weighed 37 ounces and had a volume of approximately 64 cubic inches. The magnetic counting circuits employ special INCREMAG units which provide for compactness, reliability and low power consumption. (The INCREMAG is a development of the General Time Corporation.) Each timing and sequencing unit (Figure 18) consists of the following electronic and electromechanical units:

- (1) A crystal controlled Oscillator-Amplifier which provides clock pulses at a frequency of 18 kc.
- (2) An INCREMAG counting train which divides the 18-kc Oscillator frequency to a pulse rate of 0.5 pps. This is designated the A counting train.
- (3) Switching circuits which are driven from the output of this counting train to perform some of the clock functions.
- (4) A second INCREMAG counting train which divides the 18-kc Oscillator input frequency to provide the Recorder-Sync and Horizontal-Sync pulse outputs. This is designated the C-circuit board counting train.
- (5) A magnetic storage circuit consisting of a third INCREMAG counting train. This circuit is the same in principle of operation as the other INCREMAG trains in the system and is referred to as the B storage train.
- (6) A fourth train designated the direct picture INCREMAG counter. This train divides the recorder sync output of the C train to provide output pulses which perform the same function as the A train pulses. The former source is used in the direct picture mode, the latter for remote operation. (The system is designed to time intervals up to 5 hours in

duration. Any interval from zero to maximum storage, in two-second increments, may be set.)

After the last set pulse, a gate is opened by the start command admitting 18-kc pulses to the A counting train. This frequency is successively divided by six INCREMAG stages in the A counting train to provide the .5 pps pulses. At the same time another gate is also opened, admitting the .5 pps pulses to the B-storage INCREMAG train. When the B-storage circuit is filled with pulses, it provides an output pulse. This pulse is applied to a flip-flop to start the electro-mechanical train. (These circuits run continuously during the life of the satellite.)

The C counting train contains two INCREMAG stages which divide the 18-kc oscillator frequency by 36, giving a 500-pps output. This is further divided by a bi-stable multivibrator circuit to provide the 250-pps horizontal-sync pulses.

Pulses of the desired width are obtained by using bi-stable multivibrators controlled by different INCREMAG outputs; these are turned on by one INCREMAG output pulse, and turned off by an output from another INCREMAG in the same train. For example, the second six-counting INCREMAG stage of the C train turns on a flip-flop 500 times per second. The first 6 counter of this train delivers a pulse 333 microseconds after that of the second counter. This pulse turns off the flip-flop. The flip-flop is therefore on for approximately 320 microseconds. By using this technique throughout the system, various desired pulse-widths are obtained.

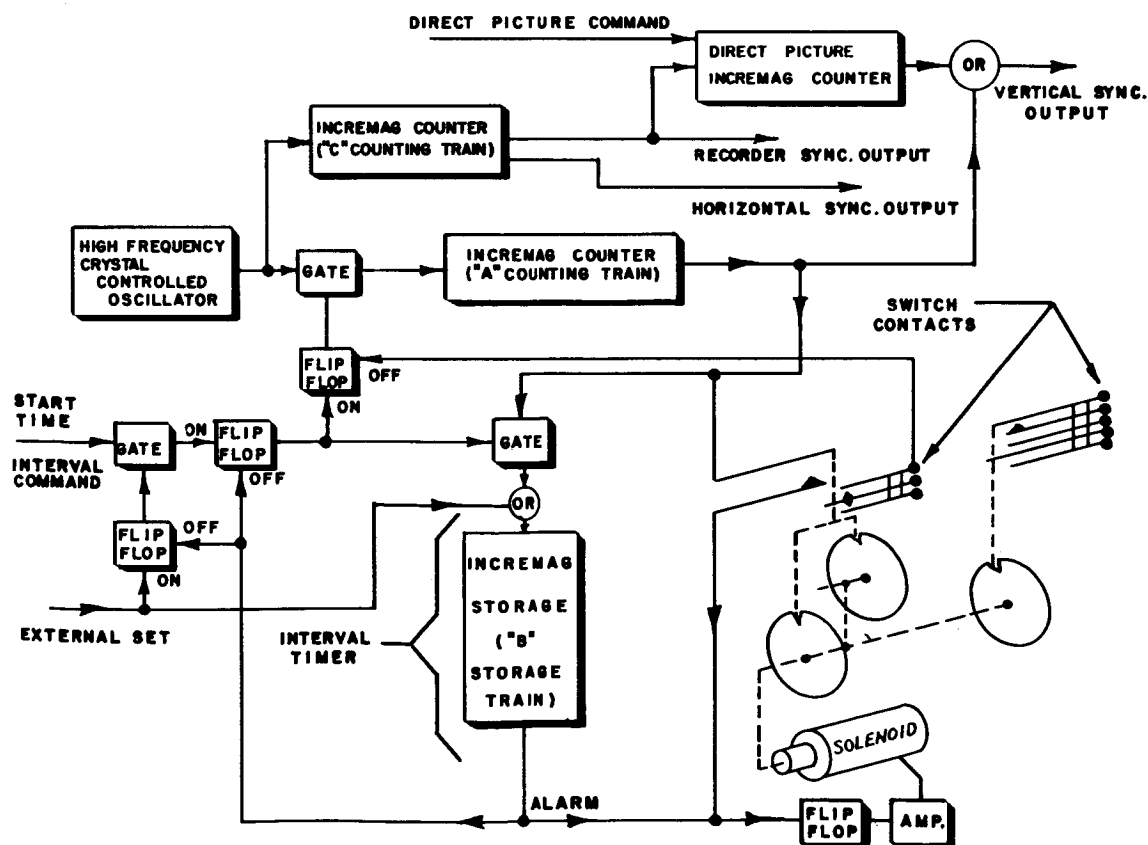


Figure 18. Timing and Sequencing, Block Diagram

SECTION III

(1) Remote-Picture Mode of Operation

When a series of pictures are desired at a point on the earth which is between, and out of communication range of two ground stations, clock-set pulses are transmitted to the satellite (while within communication range) from a ground station. These pulses are applied to, and stored in the B-circuit board which sets the clock to the desired time interval.

(2) Direct Picture Mode of Operation

When it is desired to take pictures while the satellite is under direct ground control, it is not necessary to set the clock system or provide the internal switching sequence as in the remote-picture mode of operation. The circuits can be energized, the shutter actuated and the vidicon scanned by ground-initiated commands. (The tape recording is not required.)

In this mode, the only command to the clock that is required is a steady tone signal to enable the direct-picture INCREMAG Counter. However, a sequence of ground-transmitted signals must be sent to the satellite to energize the vidicon circuits, enable the direct picture INCREMAG counter, and actuate the shutter. The first vertical-sync pulse following the exposure scans the vidicon for readout. This readout is instantaneously transmitted to the ground.

After taking and receiving the desired direct pictures, the video circuitry is de-energized and the direct picture INCREMAG is disabled by ground command.

(3) Counting Circuit Description

The INCREMAG is a transistorized magnetic counting circuit which delivers an output pulse after having received (and stored) a predetermined number of input pulses. It is automatically reset during the delivery of the output pulse so that another count can be started immediately. The value of the count is adjustable and can be set to any number of pulses up to 16 per stage. Multiple stages can be cascaded to obtain any desired count. This device serves as an excellent storage medium, and power failures have no effect on the memory. Each INCREMAG counter consists of one high-permeability magnetic core with multi-tapped windings; two transistors are also used in each INCREMAG stage. The magnetic core serves as a storage medium which is filled by discreet increments of magnetic flux. To provide a count of ten, for example, ten increments of flux must be applied. When the last flux increment is applied, the circuit delivers an output pulse and resets. These increments of flux must always be constant to maintain a constant count. For this reason, the first counter in each INCREMAG train is driven by a pulse-forming circuit which provides constant flux increments. This is essentially a one-counting INCREMAG. It acts as a constant-volume-ladle to fill the bucket (magnetic core) of the first stage.

Eight of the nine flip-flops used in the TIROS Clock and Sequence Timer are of the complementary symmetry type, using PNP and NPN germanium transistors. When these are in the off condition neither of the transistors conducts. This feature reduces the standby battery drain of the system.

4. Functional Description

a. Camera-Control Unit

The following is a detailed description of the command logic. The description will center about the camera control unit CCl-1 but it also applies to CCl-2 which is identical in function. A block diagram of the command system is shown in Figure 19.

(1) Direct Camera

When the command transmitter is modulated by tone D, this signal is filtered and detected by F13. Command tones are transmitted one at a time at 80% modulation. The resulting d-c output is amplified to operate Relay K1. This applies power to: (a) DCI-1, the dc-dc converter, to start heating the television-transmitter filaments, (b) CEI-1, to energize the television camera, and (c) the 28-second delay circuit (D11) in CCl-1. At the end of the 28-second delay, (during the delay the satellite power is interlocked so that none of its picture read-out functions can operate) relay K2 operates from power supplied by D11. When relay K2 is operated, power is applied to the circuits listed in Table 1.

Once the satellite is activated (after the 28-second delay), direct television pictures are generated each time that the direct camera tone is interrupted for longer than 1.2 seconds. An absence of signal (no tone) at NAND 11 causes Schmitt-trigger T11 to change state. This turns FF11 on and enables gate 11. The next vertical-sync pulse from the clock (CSP1), triggers FF12 on. This trigger snaps the shutter. The next vertical-sync pulse (2 seconds later), turns FF12 off. During this 2-second interval, power is supplied the video-subcarrier oscillator in the recorder electronics to read out the picture as it is scanned. Note that the picture read-out does not occur coincident with the command, but waits for vertical sync to start with the beginning of scan.

A 26-second off delay circuit (D12) keeps the satellite active, without a primary command (direct camera or play-back) present, to time-share other commands; i.e., picture read-out, clock set, clock start, beacon kill, etc.

In the absence of a signal at NAND 11, trigger T11 changes state as described previously. This unclamps a timing capacitor in D12, starting the delay. After 26 seconds, an output from D12 causes K2 to turn off, returning the satellite to standby. Note that if a primary command is interrupted for less than 26 seconds, the timing capacitor in D12 is clamped to its time = zero (T_0) voltage, thus recycling and holding the delay time at zero.

(2) Playback

The playback command is accomplished in a manner similar to the direct command as far as the 28-second on and 26-second off delays are concerned, but instead of K1 closing on the command, playback relay K3 closes.

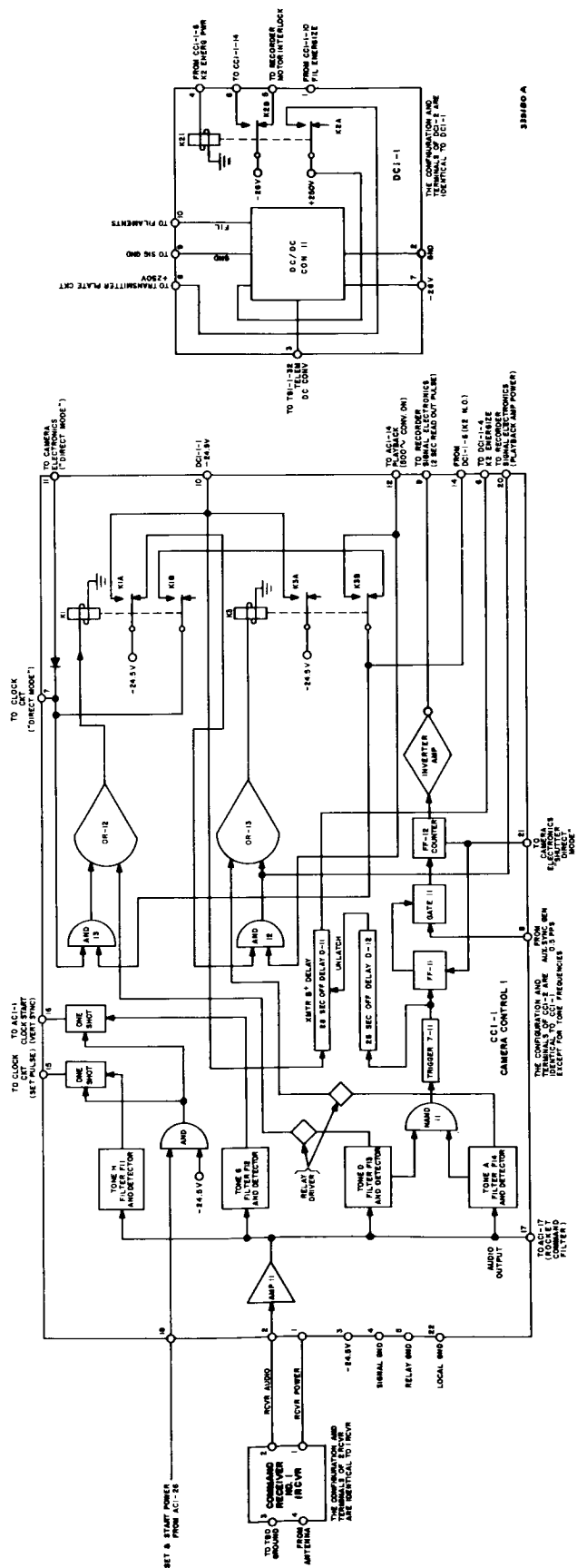


Figure 19. Satellite Command System, Block Diagram (Sheet 1 of 2)

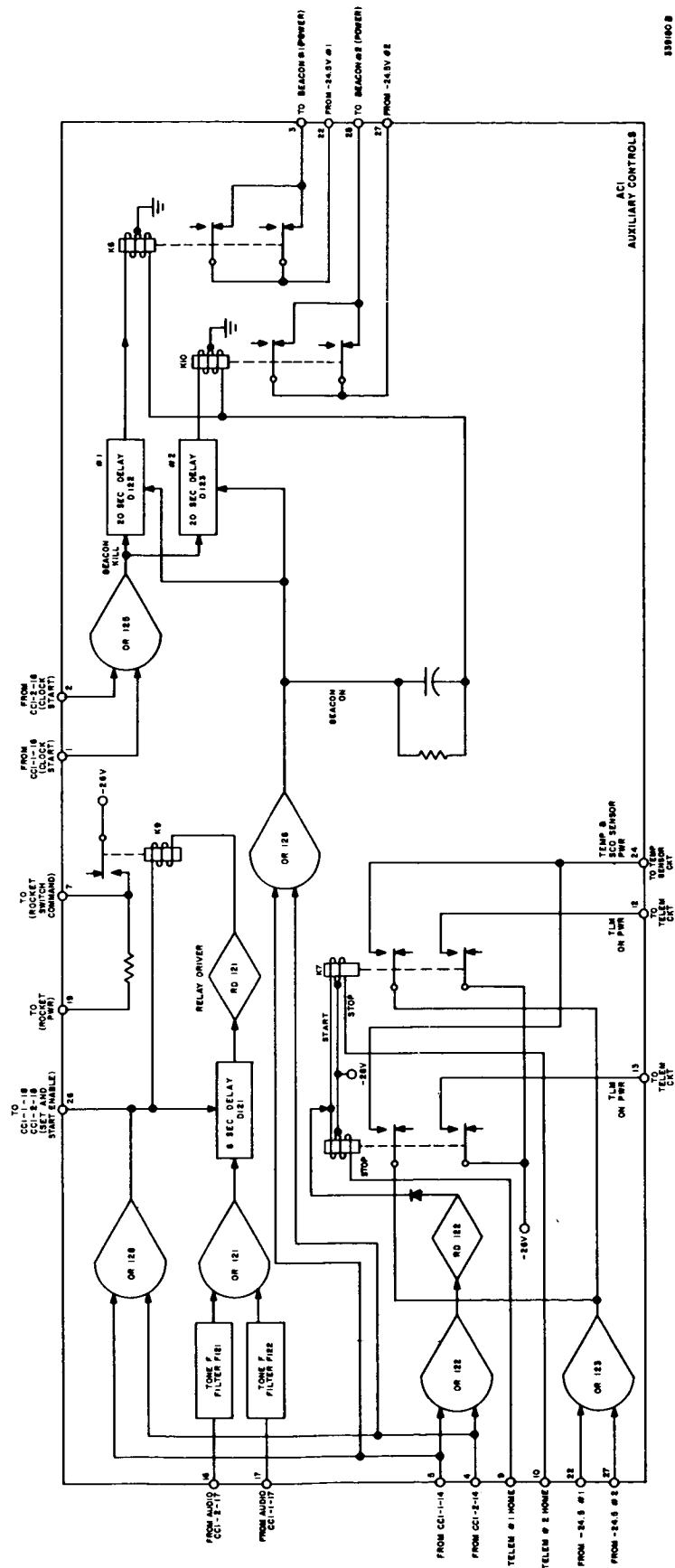


Figure 19. Satellite Command System, Block Diagram (Sheet 2 of 2)

SECTION III

Table 1. Power Application at End of 28-Second Time Delay

Circuit	Function
Television Transmitter High Voltage Power Supply	Enables television transmitters
Relay Driver RD122	Activates <u>latch-on</u> relays K1207 and K1208 and thereby energizes the multivibrator circuits which drive the telemetry switches at a one-step-per-second rate. (After 40 steps, one complete revolution, the telemetry switches are at their home positions and automatically stop.)
Contacts on Relay K2	Provides holding or lock-up power for the relay
26-Second Off Delay Circuit	Enables the circuit so that it will begin timing when the <u>direct camera</u> tone is interrupted
Direct Camera Circuits of the Clock (CSP-1)	Provides horizontal and vertical synchronizing pulses for use by the television camera
<u>Clock Set</u> and <u>Clock Start</u> Circuits	Enables the circuits so that they will respond to <u>set</u> and <u>start</u> pulses

At the end of the 28-second delay, K2 closes energizing the 500 cycle dc-to-ac converter through K3, which operated 28 seconds earlier. The tape recorder then plays back until a metalized strip at the end of tape closes a circuit and automatically turns the motor power off. Again, if the command tone is interrupted for less than 26 seconds, the circuit recycles and holds the delay time at zero as in the direct picture mode of operation.

The satellite command system can be transferred from the playback mode to the direct mode and vice-versa, instantaneously, merely by changing the appropriate command tones.

(3) Clock-Set and Clock-Start

Remote picture-taking is accomplished by setting the clock, on command, to alarm and initiate a picture-taking sequence with a delay from zero to five hours. This is accomplished by storing the complement of the delay time in a storage counter which has a capacity of 9000 counts. Each count corresponds to a 2-second delay. Each set pulse, stored in the counter, subtracts 2 seconds from an 18,000-second delay. Set pulses are stored one at a time without coding. The clock set is usually accomplished during playback.

After the satellite is active, a predetermined number of clock-set tone bursts are transmitted. Both clocks are set simultaneously by using different clock-set tone frequencies. The tone bursts are interleaved with the primary command tone (either playback or direct) so that the trigger T-11 does not change state and start the 26-second delay. Starting the delay would place the satellite in the standby mode.

Set pulses are transmitted at a rate of 130 pps. These bursts are detected by filter-detector F11 which, in turn, triggers a one-shot multivibrator where period is longer than the tone burst. Thus, one set pulse is generated for each tone burst.

After the clock has been set to the proper delay time, a start command is transmitted at a precise time to permit remote picture-taking to occur at a known accurate time.

The start command is a tone burst of an 8-second duration. This tone is detected by filter-detector F12 and applied to a one-shot multivibrator. The first few milliseconds of the start-tone burst generates short pulses; the remaining portion of this tone generates a d-c output from the one shot. The initial pulses start the clock timing, while the steady d-c output is used to accomplish the beacon kill command.

b. Auxiliary-Control Unit

(1) Beacon-Kill Command

When it is desired to discontinue transmitting from the two beacon transmitters, they can be turned off by command. To accomplish, this a clock start tone is transmitted for approximately 20 seconds. This command starts the timing action of delay circuits D122 and D123. These circuits are identical to those used for the 28-second on and 26-second off delay circuits. At the end of the timing cycle, relays K6 and K10 are unlatched, turning off the beacon power. If it has been desired to turn the beacon on again, either primary command from either system would have latched both relays on.

(2) Spin-Up Rocket Fire Command

The spin-up rockets were fired by command tone F from either system 1 or system 2. This tone was filtered and detected, and the d-c output was fed to six-second delay circuit D121. At the end of the delay, a relay closed, energizing a solenoid stepping switch which fired a pair of rockets immediately upon moving to a new position.

5. Acceptance Tests

A complete acceptance test of the command system was performed on a subsystem level. The units were tested first at room pressure at temperatures of -10°C , $+25^{\circ}\text{C}$ and $+60^{\circ}\text{C}$. Then the test was repeated on a Go, No-Go basis in a vacuum chamber

SECTION III

at a pressure of 5×10^{-5} Hg for three complete cycles at temperatures of 0°C, +25°C, and +50°C. The test results are listed in Table 2. A description of the test parameters is contained in the following list:

Item

- 1 Audio-amplifier bias
- 2, 3 Audio-amplifier output with limit signals from receiver
- 4 Sensitivity of direct command without setting
- 5 Sensitivity of Schmitt trigger during direct without setting
- 6 Sensitivity of direct command while setting
- 7 Sensitivity of Schmitt trigger during direct while setting
- 8 Latching voltage for K_1
- 9 2-second read supply voltage
- 10 Rise time of shutter pulse
- 11 Sensitivity of playback command without setting
- 12 Sensitivity of Schmitt-trigger during playback without setting
- 13 Sensitivity of playback command while setting
- 14 Sensitivity of Schmitt trigger during playback while setting
- 15 Latching voltage for K_3
- 16 Voltage supplied to playback amplifier
- 17 Set-clock pulse width
- 18 Set-clock pulse rise time
- 19 Set-clock pulse fall time
- 20 Set-clock pulse amplitude
- 21 Spurious set-pulse test
- 22 Ability to set clock without error
- 23 Sensitivity of start-clock command 1
- 24 Sensitivity of start-clock command 2
- 25 Spurious start-clock test
- 26 Ability to start clock
- 27 Regulated-voltage test
- 28 28-second delay adjust and test
- 29 26-second delay adjust and test

Table 2. Camera Control Unit Acceptance Tests

Item	Section	Test Point	Test Condition	Units of Measurement	Test Temperatures and Measurements		
					-10°C	+25°C	+60°C
1	Audio Amplifier	VQ _{2e}		Volts d-c		11	11
2		17	0.5v rms at terminal 2	Volts rms		1.4	1.35
3		17	1.5v rms at terminal 2	Volts rms		3.8	3.6
4	Direct Camera	2	K ₁ Actuate; No Set	Volts rms	0.37	0.28	0.25
5		2	Q ₂₆ On; No Set	Volts rms	0.37	0.3	0.27
6		2	K ₁ Actuate; Set Pulses	Volts rms	0.6	0.44	0.4
7		2	Q ₂₆ On; Set Pulses	Volts rms	0.6	0.48	0.43
8		A	After K ₂ On	Volts d-c		24	
9		9	500-ohm Load	Volts d-c	23	23.5	23.5
10		21	Shutter-Pulse Rise Time	μsec	1.5	1.5	2
11		2	K ₃ Actuate; No Set	Volts rms	0.37	0.29	0.27
12	Playback	2	Q ₂₆ On; No Set	Volts rms	0.41	0.35	0.32
13		2	K ₃ Actuate; Set	Volts rms	0.58	0.47	0.44
14		2	Q ₂₆ On; Set	Volts rms	0.66	0.57	0.53
15		D	After K ₂ On	Volts d-c		24	
16		20	After K ₂ On	Volts d-c	24	24	24

Table 2. Camera Control Unit Acceptance Tests (Cont.)

Item	Section	Test Point	Test Condition	Units of Measurement	Test Temperatures and Measurements		
					-10°C	+25°C	+60°C
17	Set Clock	15	Pulse Width (1v rms at terminal 2)	millisec	1.9	2	2.2
18		15	Rise time	μ sec	2	1.5	2
19		15	Fall time	μ sec	3	4	3
20		15	Pulse Amplitude: Without clock With clock	Volts Volts	20 14	20 14	20 14
21			Spurious Pulse: Enable Crosstalk		OK OK	OK OK	OK OK
22			Set Clock		OK	OK	OK
23		16	Input at terminal 2 for d-c output	Volts rms	0.66	0.48	0.43
24	Start Clock	16	1.0v rms at terminal 2	Volts d-c	23.5	23.5	23.5
25			Spurious Pulse: Enable Crosstalk		OK OK	OK OK	OK OK
26			Start Clock		OK	OK	OK

Table 2. Camera Control Unit Acceptance Tests (Cont.)

Item	Section	Test Point	Test Condition	Units of Measurement	Test Temperatures and Measurements		
					-10°C	+25°C	+60°C
27	B + Delay	3	Supply-voltage check	Volts d-c	24.5	24.5	24.5
28		10	Delay	seconds	1-at 0°C 2-27.37 3- ---	1-28.65 2-28.29 3-28.39	1-29.47 2-29.30 3-29.06
29	Off Delay	10	Delay	seconds	1- --- 2-26.30 3- ---	1-26.56 2-26.68 3-26.46	1-26.73 2-26.65 3-26.63

6. Auxiliary Circuits

a. Operation

It was required, after separation of the third stage and payload during the launch sequence, that the satellite be revolved around its spin axis at approximately 120 rpm. This spin rate was required to stabilize the satellite and the third stage. At separation, precession dampers were immediately released by separation switches (see Figure 20), which also initiated the operation of the delayed timer at this time. The delay timer was primarily required to deliver a voltage to fire the squibs which, in turn, released the despin weights after a time delay of 4 to 14 minutes. This delay was necessary to permit sufficient time for the precession dampers to effect stabilization of the satellite about its true spin axis. It was anticipated that the 5 minutes nominal time would provide sufficient time for the spin stabilization.

The despin timer, at the end of 5 minutes, closed relays which applied to the battery voltage across the squibs. The squibs released the despin weights which cause the satellite to slow down to a rotational velocity of between 9 and 12 revolutions per minute. A second important requirement for this circuitry was that it be completely redundant; therefore, two identical separation switches were connected in parallel to initiate the events. The mass release and precession damper mechanisms each employed two piston squibs in such a manner that firing of either or both would actuate the mechanisms. Two parallel time-delay circuits (see Figure 21), were employed to control the firing function.

The delay circuits were connected in such a way that the one with the shortest time delay would fire the mass-release squibs. (Refer to Figure 21). At the end of the time delay, relay 1K1 or 2K1 is energized by the delay circuit and two pairs of contacts are closed to apply -26.5 volts from the unregulated power supply to the mass-release squibs. When the masses are released, mass-release switches S2 and S3 (either one or both) open the connection to the unregulated power supply and prevent any additional power drain regardless of any failure in the timer or squib circuits. To provide further reliability, the rocket-fire switch may be manually controlled from a ground station to provide the voltage to fire the despin squibs.

To provide some protection against induced r-f currents, the squibs and spin-up rockets were shunted with 0.01 microfarad capacitors. For this application, capacitors with very low inductance were selected to provide a low-impedance shunt at very high radio frequencies.

Each spin-up rocket or piston squib required 300 milliamperes of current for firing. Resistors R2, R3, R4, R5, and R6 series protect the spin-up rockets and squibs while the separation switches are open. The circuit is arranged to utilize these resistors for continuity check of these components, and the current (using 27 volts d-c for checking) never exceeds approximately 0.5 milliamperes. The shorting deck of the rocket-firing switch S1B is utilized to provide grounding of the rocket terminations; note that a rocket pair is ungrounded only when it is fired on command. It is impossible to bypass the safety resistors through any plug, jack, or test receptacle.

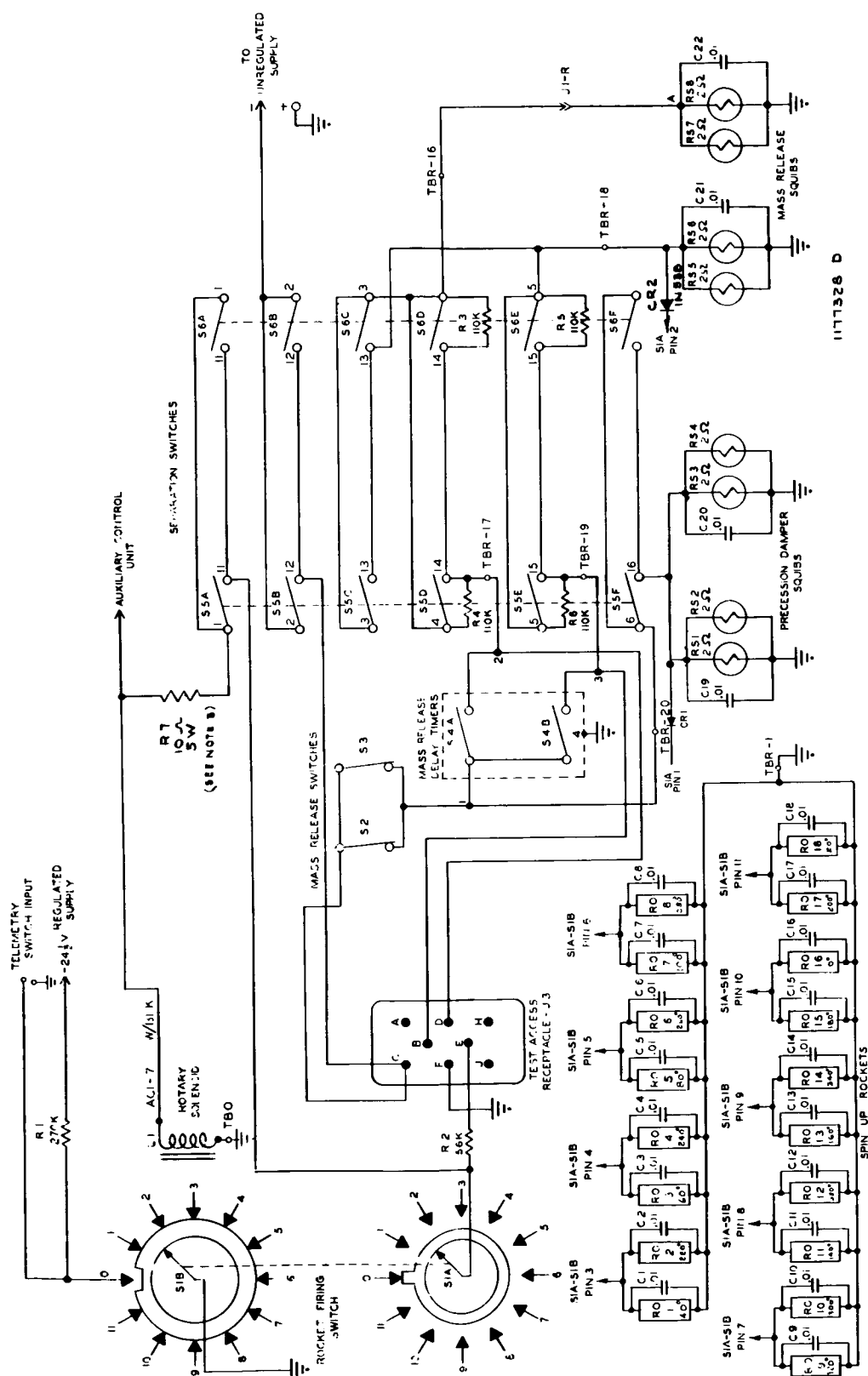
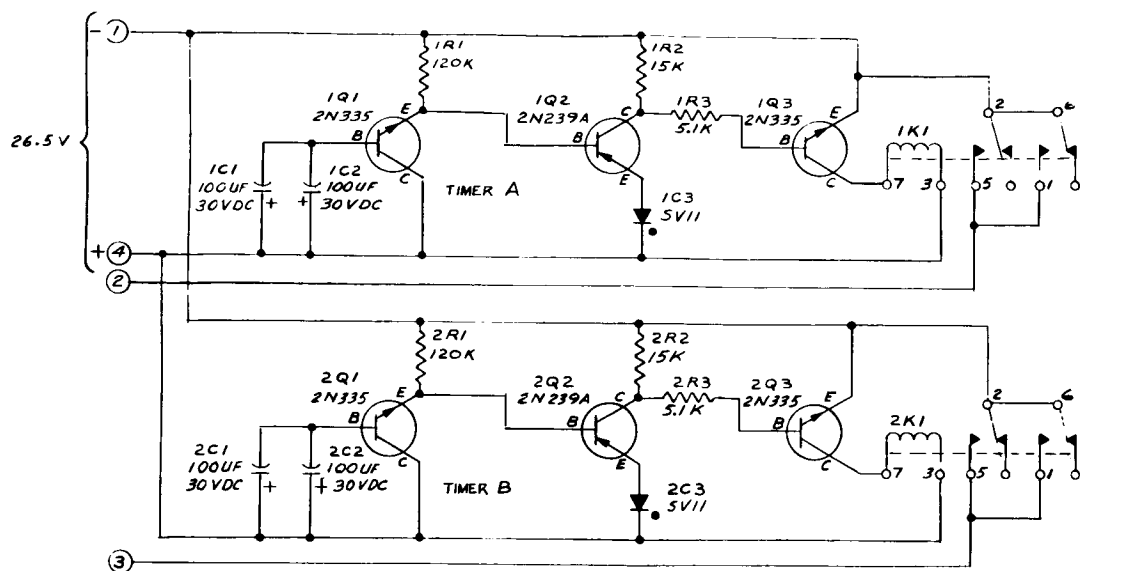


Figure 20. Separation Event Schematic and Rocket Wiring Diagram

SECTION III



NOTE

NOTE
1. ALL RESISTORS ARE $\frac{1}{4}$ WATT AND RESISTANCE VALUES ARE IN OHMS EXCEPT AS NOTED.

2. FOR LIST OF PARTS SEE DWG 1170353

3. TWO PARALLEL CONNECTED TIME DELAY CIRCUITS FOR ONE ASSEMBLY.

Figure 21. Mass Release Time Delay, Schematic Diagram

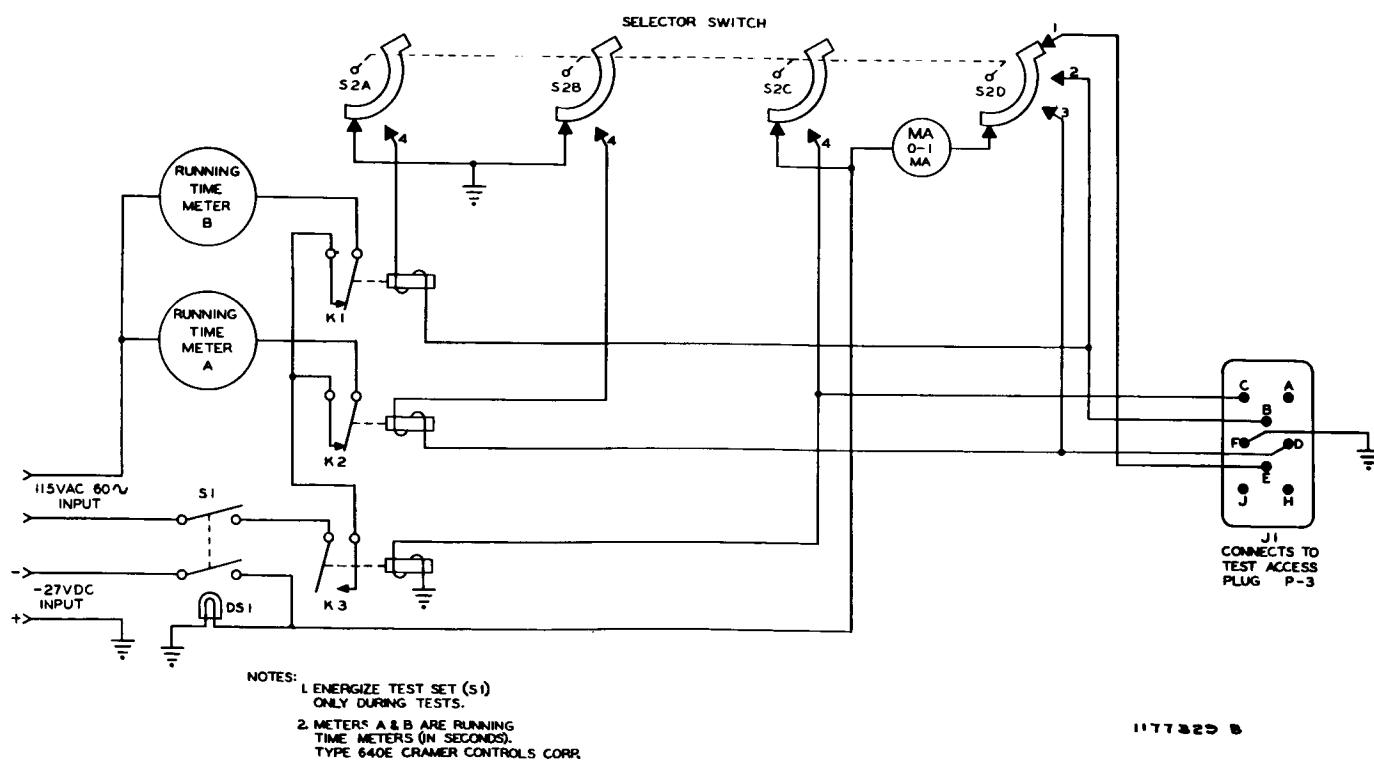


Figure 22. Squib, Rocket and Timer Test Set, Schematic Diagram

It was essential that the satellite be launched with the spin-up rocket firing switch indexed to the zero position. The rocket firing switch zero index was telemetered through position 23 of the number 1 Beacon by utilizing the shorting deck, S1B, as shown in Figure 20. The 270 K resistor forms a voltage divider with the telemetry switch input impedance when the rocket firing switch is indexed to zero. This divider provided an input signal of approximately 1.25 volts. At all other positions of the rocket firing switch, the telemetry input is zero.

Index positions 1 and 2 of the rocket firing switch provide for command firing of the precession damper and mass release squibs respectively. If these squibs had not been energized automatically (due to any malfunctions of the automatic sequencing circuitry) at separation, they would have been command fired through an alternate current path when the switch was indexed to the Number 1 and 2 positions.

The current supplied to the rocket switch was approximately 2.5 amperes for 2 seconds and was derived from the auxiliary control unit. Firing of the rockets by pulses rather than by a direct power connection was required to preclude power drain if a rocket presented less than infinite resistance after firing. Because a rocket pair had an approximate resistance of 1 ohm, a resistor (R7) was added to limit the firing current and thereby protect the relay contacts in the auxiliary control unit. The diodes CR1 and CR2 were placed in the alternate squib firing leads to preclude current flow through the rocket firing switch rotary solenoid via the separation switches, when the rocket firing switch was indexed to the Number 1 or 2 position. Without these diodes, the solenoid would have held and not released the switch for further command indexing. The rocket firing switch functions and the separation switch functions are summarized in the following two tabulations.

ROCKET FIRE SWITCH FUNCTIONS

INDEX	FUNCTION
0	Switch index telemetered
1	Second chance firing of precession damper squibs
2	Second chance firing of mass release squibs
3	Spin-up rockets 1 and 2 fired
4	Spin-up rockets 3 and 4 fired
5	Spin-up rockets 5 and 6 fired
6	Spin-up rockets 7 and 8 fired
7	Spin-up rockets 9 and 10 fired
8	Spin-up rockets 11 and 12 fired
9	Spin-up rockets 13 and 14 fired
10	Spin-up rockets 15 and 16 fired
11	Spin-up rockets 17 and 18 fired

* Actually, only two pairs of spin-up rockets were carried by TIROS I; the remaining switch positions were not connected. Refer to Paragraph 2.III.A.7.d of the main text.

SEPARATION-SWITCH FUNCTIONS

CONTACTS	FUNCTION
A	Rocket firing switch armed
B	Mass release time delay initiated
C	Mass release squibs and timers commonly connected
D	Squib safety resistors R3 and R4 shunted
E	Squib safety resistors R5 and R6 shunted
F	Precession damper squibs fired

b. Tests

A test-set circuit was designed (Figure 22) to mate with the test access receptacle shown in Figure 20 for continuity checking of all squib and rocket circuitry and the mass-release time delays. Small currents of approximately 0.5 milliamperes are used for continuity checks and running time meters are used to show operation of each of the two parallel connected time delay circuits. The rocket firing switch was commanded to run the sequence of tests.

The test set contained internal batteries for emergency use, but it was intended that an external supply capable of delivering 325 milliamperes at 27 volts be employed if possible.

Allowing for resistor and supply voltage tolerance, the milliammeter indication was required to be from 0.4 to 0.6 milliamperes for the continuity checks. The current indication was governed by the safety resistors shown in Figure 20 because the resistance of the rockets and squibs were negligible. The squib circuit for each mass release mechanism was checked independently because of the critical nature of these components. A list of test set operations is shown in Table 3.

The mass release time delay circuits were designed for a nominal 300-second delay at room temperature with 27 volts d-c input. An indication for each time delay of 240 to 840 seconds was acceptable. Close tolerance components were not used in these time delays; therefore, different values were obtained for different timers. The running time meters automatically record the elapsed time when they have been manually set to zero before making the tests.

Table 3. Test Set Operations

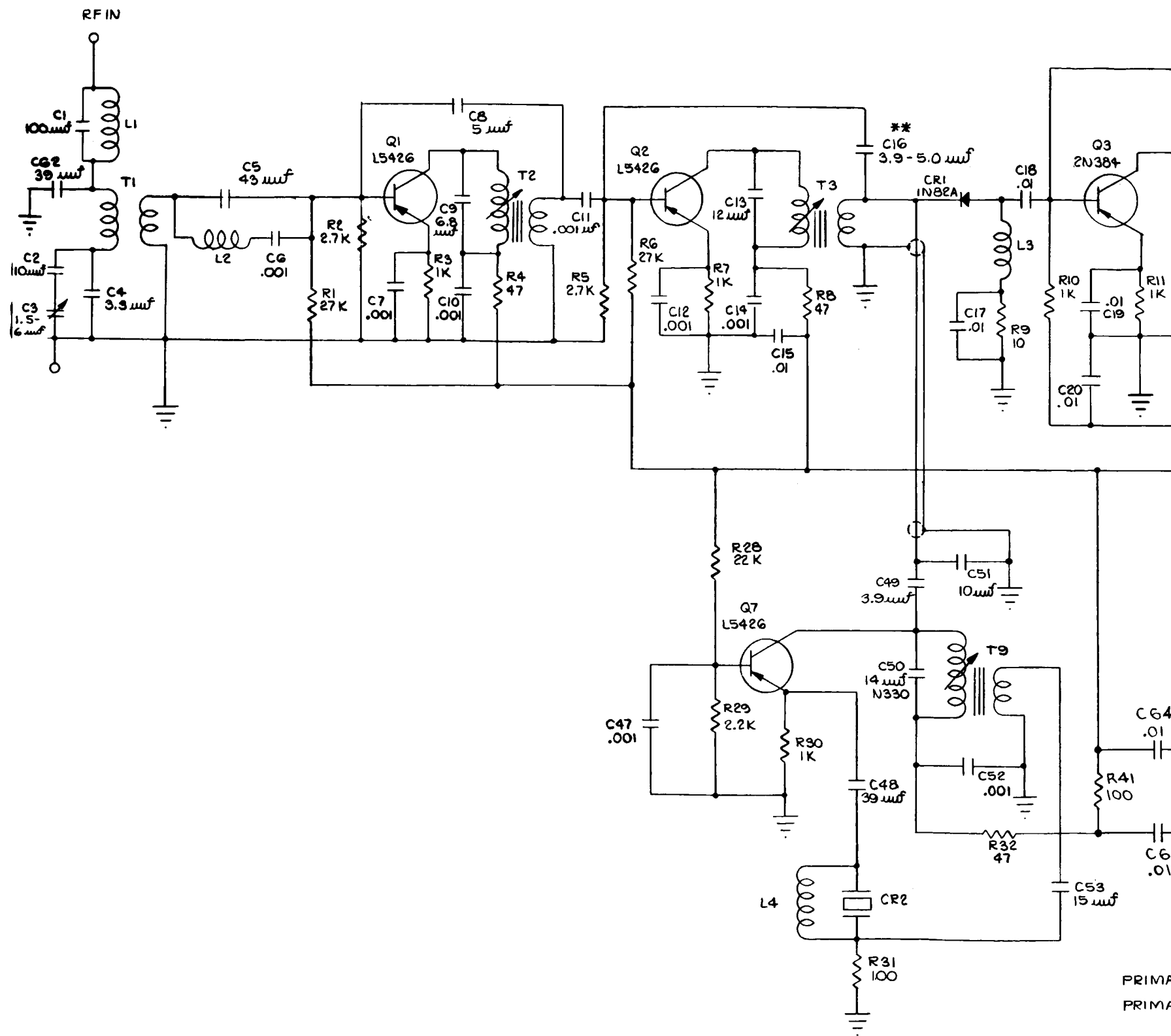
Test No.	Selector Switch Setting	Rocket Firing Switch Setting	Component and Circuit Checked	Indicator	Satisfactory Indication
1	1	1	Precession Damper Squibs 1, 2, 3 & 4	Milliammeter	0.4 to 0.6 Milliampere
2*	1	2	Mass Release Squibs 5 & 6	Milliammeter	0.4 to 0.6 Milliampere
3	1	3	Rockets 1 & 2	Milliammeter	0.4 to 0.6 Milliampere
4	1	4	Rockets 3 & 4	Milliammeter	0.4 to 0.6 Milliampere
5	1	5	Rockets 5 & 6	Milliammeter	0.4 to 0.6 Milliampere
6	1	6	Rockets 7 & 8	Milliammeter	0.4 to 0.6 Milliampere
7	1	7	Rockets 9 & 10	Milliammeter	0.4 to 0.6 Milliampere
8	1	8	Rockets 11 & 12	Milliammeter	0.4 to 0.6 Milliampere
9	1	9	Rockets 13 & 14	Milliammeter	0.4 to 0.6 Milliampere
10	1	10	Rockets 15 & 16	Milliammeter	0.4 to 0.6 Milliampere
11	1	11	Rockets 17 & 18	Milliammeter	0.4 to 0.6 Milliampere
12	2	0	Mass Release Squibs 5 & 6	Milliammeter	0.4 to 0.6 Milliampere
13	3	0	Mass Release Squibs 7 & 8	Milliammeter	0.4 to 0.6 Milliampere

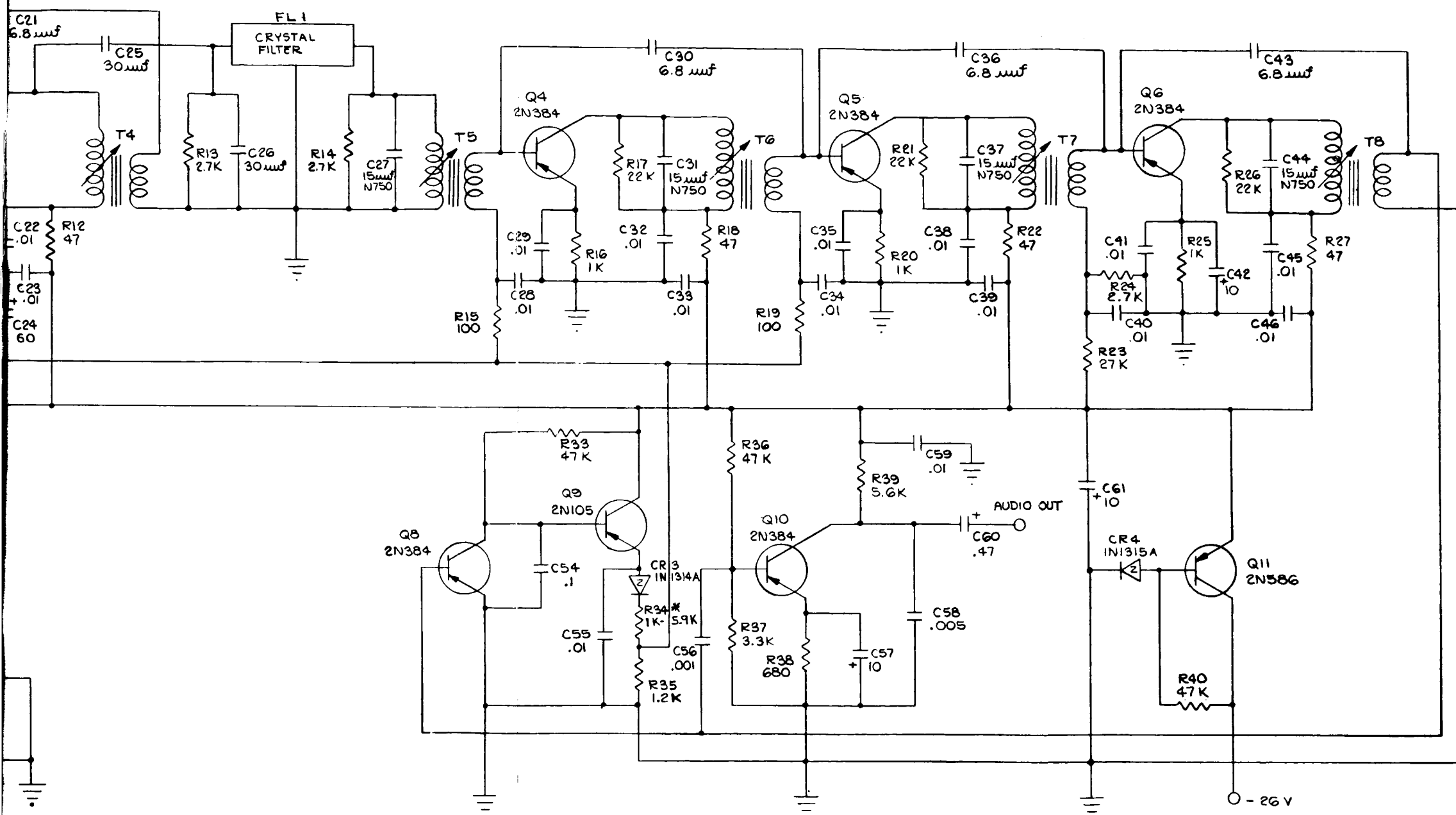
*Test No. 2 normally omitted; it is redundant to test No. 12.

SECTION III

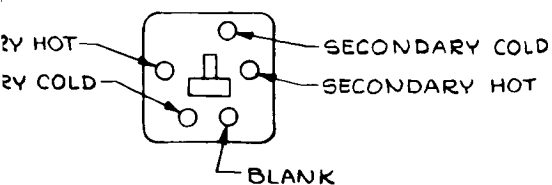
Table 3. Test Set Operations (Cont.)

Test No.	Selector Switch Setting	Rocket Firing Switch Setting	Component and Circuit Checked	Indicator	Satisfactory Indication
14	4	0	Mass Release Timer A	Running Time Meter A	240 to 840 seconds
			Mass Release Timer B	Running Time Meter B	240 to 840 seconds
			Mass Release Switches closed (Either/Both)	Running Time Meters (Either/Both)	Time Delay Recorded





IF TRANSFORMER BASE



* TO GIVE .45V DC ACROSS R11, R14, R20

** 3.9 μ f TO BE USED IF A 5.0 μ f CAUSES Q2 TO OSCILLATE

NOTES:

1. ALL RESISTANCE VALUES ARE IN OHMS.
2. ALL CAPACITOR VALUES ARE IN μ f UNLESS OTHERWISE NOTED.
3. FOR ELECTRICAL PARTS LIST SEE DWG A-1170347

1176109A

Figure 12. Satellite Command Receiver, Schematic Diagram

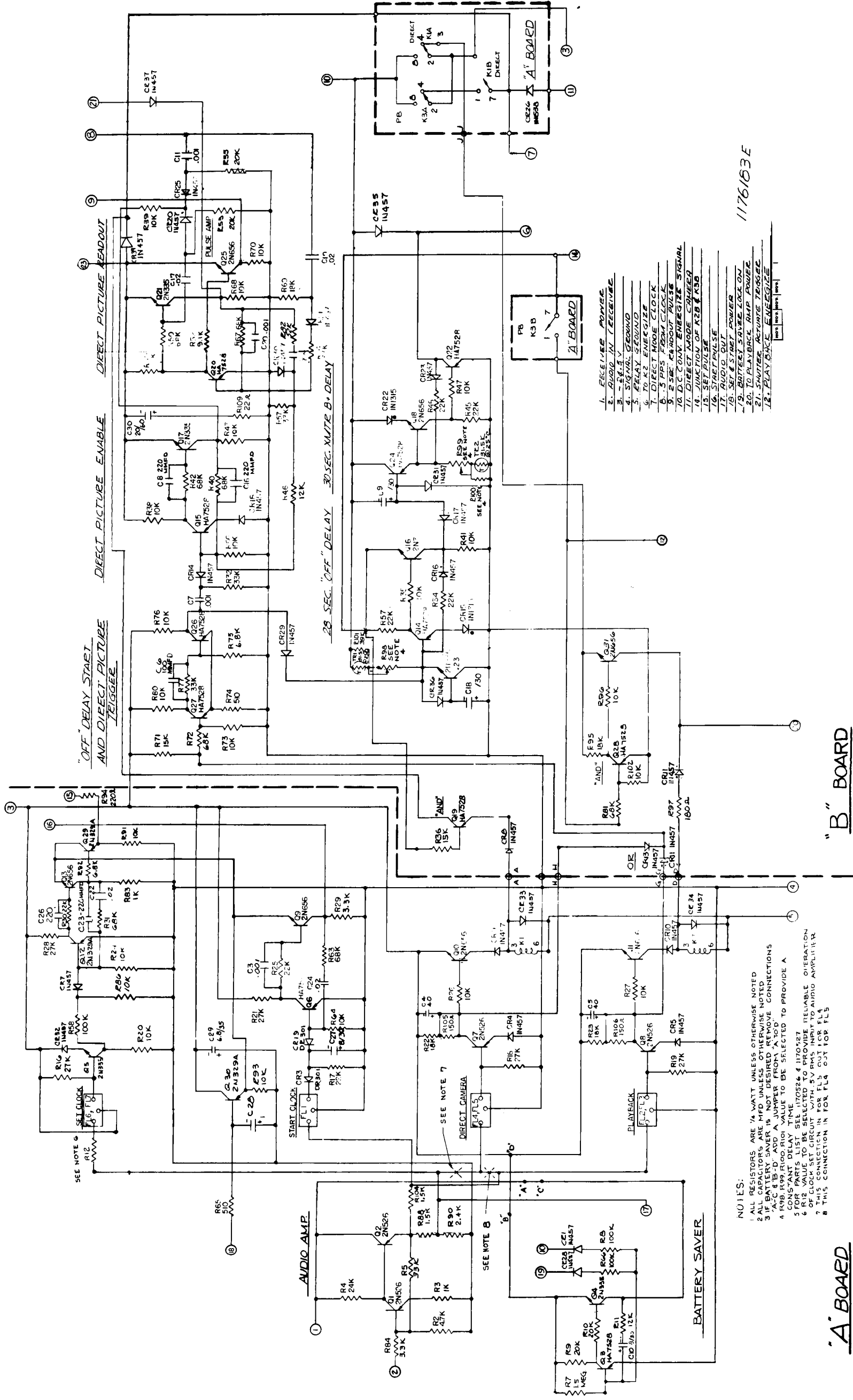


Figure 15. Satellite Camera Control Unit, Schematic Diagram

SECTION IV. GROUND COMPONENTS

A. CONTROL TONE GENERATOR

1. General

The control tone generator was designed to produce ten audio-frequency tones at the time that three camera channels were specified for the TIROS satellite. When the requirement was reduced to two channels, fewer tones were needed; but for the final design it was found convenient to use all but one. Selection of a particular control tone was performed automatically as a result of the setting of the command programmer and subsequent action of the remote picture time set unit.

The accuracy requirement of the control tones was not very stringent; the only requirement was that the tone had to be within the pass band of the corresponding filter in the satellite control package. Although LC or RC oscillators could have been used in this application, RCA chose to use tuning forks to generate the control tones in order to increase reliability by eliminating the possibility of human errors in oscillator tuning.

The output of the control tone generator, consisting of a holding tone (corresponding to a program sequence), was interrupted by the tones for clock set, clock start, or fire spin-up rockets.* To minimize the possibility of generating spurious frequencies which might have fallen within the pass band of one of the satellite filters, a special push-pull gating circuit was devised. This circuit could be adjusted to completely cancel the pedestal on the output signal caused by the gate control voltage input.

A photograph of the control tone generator is shown in Figure 23. The ten control tones and the satellite functions which they controlled are listed in the following table.

CONTROL TONE		FUNCTION	CONTROL TONE		FUNCTION
Ref. Code	Freq. (cps)		Ref. Code	Freq. (cps)	
A	730	Playback Camera 1	F	3000	Fire spin-up rockets
B	960	Playback Camera 2	G	3900	Start clocks
C	1300	Auxiliary use only	H	5400	Set clock 1
D	1700	Direct Camera 1	I	7350	Set clock 2
E	2300	Direct Camera 2	J	10,500	Not used

* This refers to the satellite's electronic clock, which is actuated by ground command in the form of series of short pulses.

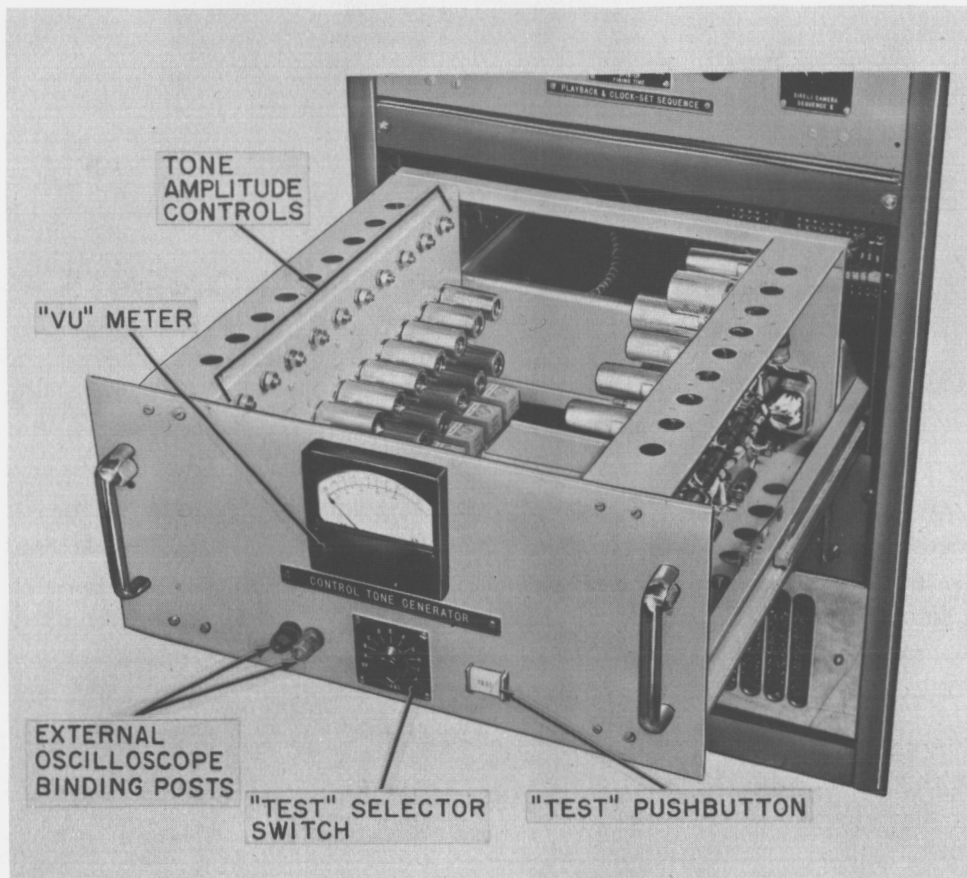
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Figure 23. Control Tone Generator, Front View

2. Functional Description

Figure 24 is a block diagram of the control tone generator. This generator consists of 10 tone generators coded (A through J), control relays, control AND gates, and an output gating circuit. Each tone generator consists of a tuning-fork controlled oscillator and the multiplier stages which are necessary to convert the oscillator frequency to the desired audio tone. Each generator produces a different continuous tone. A tone is delivered to the program selector only when enable signals are received from either the command programmer or the remote picture time set.

Depending upon the program sequence, the command programmer applies an enable signal to one of the playback lines or to one of the direct lines. If the playback 1 line is enabled (meaning that the satellite is to be programmed to playback the information stored on tape 1) relay A energizes and applies tone A to the electronic switch. Provided the switch is closed, tone A is passed through the switch, amplified and applied to the program selector.

During this playback sequence, clock set pulses can also be sent to the satellite. If clock 1 is to be set, a series of set pulses is applied from the remote picture time set to the set clock 1 control line. These set pulses are simultaneously applied to the OR

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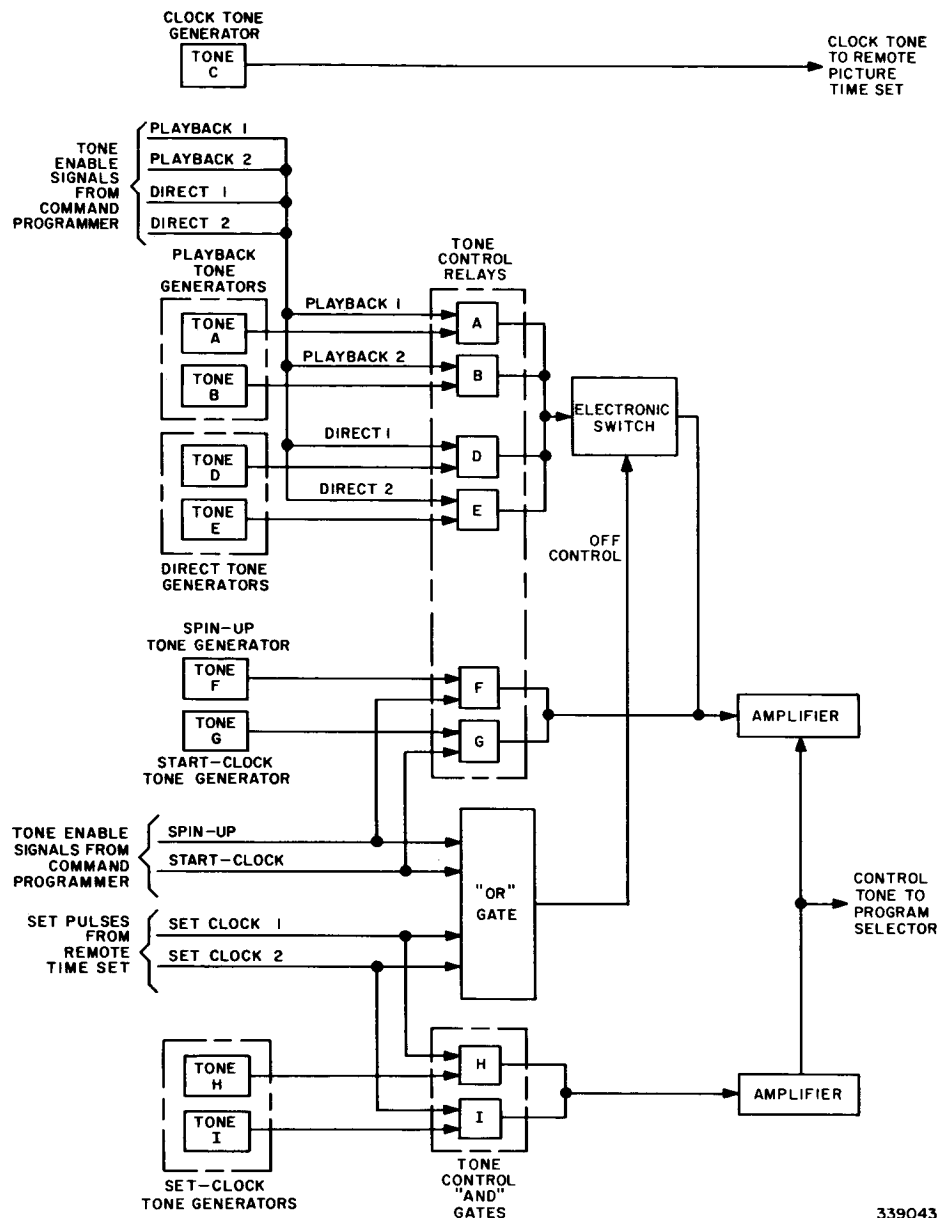


Figure 24. Control Tone Generator, Block Diagram

gate and to the tone H AND gate. Each set pulse applied to the OR gate causes the gate to open the electronic switch momentarily, interrupting the tone A oscillations; each set pulse applied to the tone H AND gate causes the gate to pass a short burst of tone H oscillations. The interrupted tone A oscillations are united with the short bursts of tone H oscillations at the output of the control tone generator. This composite signal is applied to the program selector.

Similar operation occurs if spin-up, start-clock, or set clock 2 enabling signals are applied to the control tone generator. That is, the program sequence tone (A, B, D, or E) is interrupted by the spin-up (F), start-clock (G), or set clock 2 (I) tone.

SECTION IV

Because of the amount of time involved in sending clock-set pulses, set-clock tones I and H can be interleaved on the same sequence tone.

Figure 25[§] is the schematic diagram of the control tone generator. For a detailed description of this circuit refer to "Instruction and Operating Handbook TIROS I Meteorological Satellite System."

B. REMOTE PICTURE TIME SET

1. General

The remote picture time set unit (a view of which is shown in Figure 26) generated the exact number of pulses required for setting the satellite clocks and sent these pulses to the control tone generator, to gate tone H or I, which produced the required carrier modulation.

The forerunner of the remote picture time set unit, an encoder designed by the General Time Corporation for setting the electro-mechanical clock in the JUNO satellite, was used to convert time given in hours, minutes, and seconds into the correct number of pulses for setting the mechanical alarm portion of the clock. The JUNO satellite clock alarmed when a 93-tooth wheel and a 92-tooth wheel reached their home positions in coincidence. One of the wheels was advanced one tooth at a time by pulses which occurred every 5 seconds. These pulses were generated by the electronic portion of the clock. Each complete revolution of this first wheel caused the second wheel to advance one tooth. The clock was set by stepping each wheel the correct number of points from its home position. After making a thorough study of this system, RCA reached the conclusion that there was a great possibility for error on the part of programming personnel in computing the number of steps to advance each wheel. For this reason, it was decided that a new encoder should be developed.

The responsibility for the development of this new encoder was subcontracted to the General Time Corporation along with the responsibility for developing the TIROS clock. Between 1 and 8999 pulses were required to set the TIROS clock; the exact number of pulses was dependent upon the time to be set. The number of set pulses could be calculated by using the following equation:

$$N = 9000 - \frac{t-28}{2}$$

where: N = the number of set pulses required.

t = the time interval between transmission of the start clocks, pulse and the start of picture taking sequence.

RCA considered the encoder which was proposed by the General Time Corporation to be too complex and too expensive to warrant its use in performing this relatively simple calculation. Accordingly, RCA proposed the use of a simple, four-decade preset

[§] This illustration is printed on a fold-out page located at the rear of Section IV.

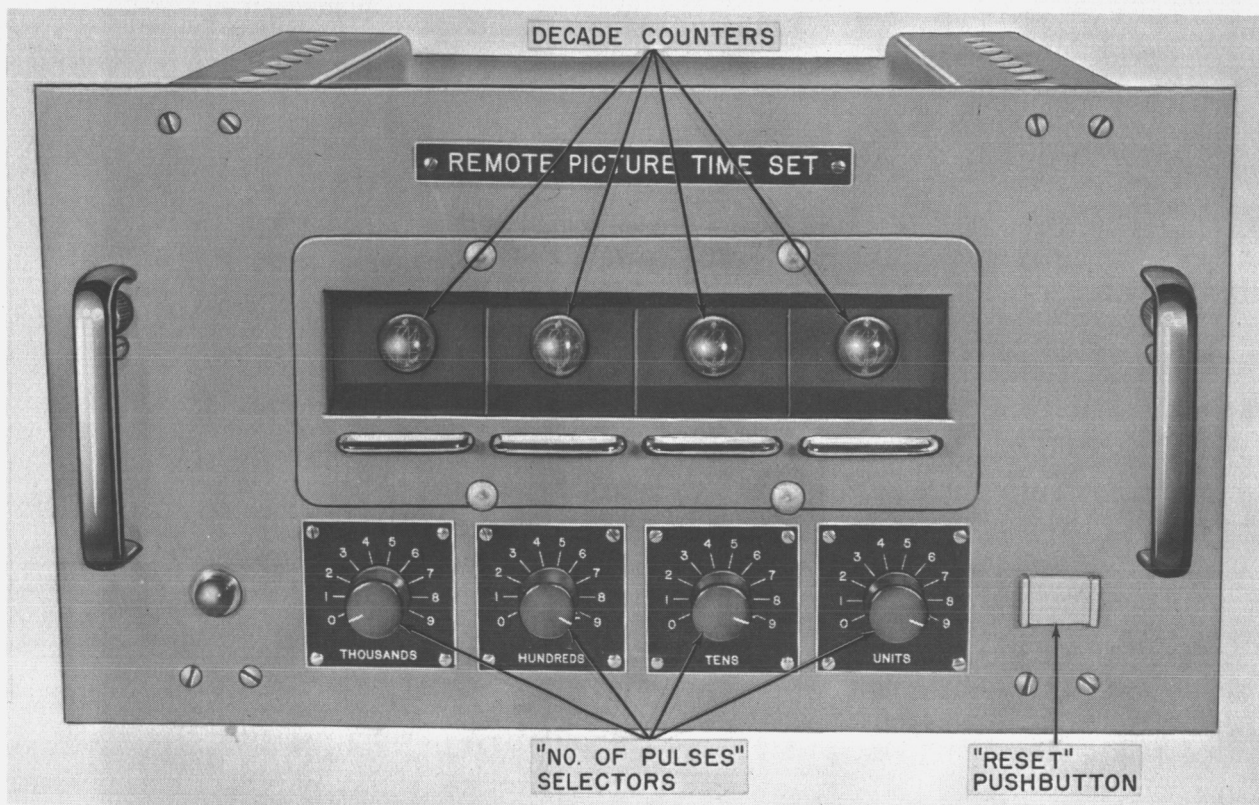


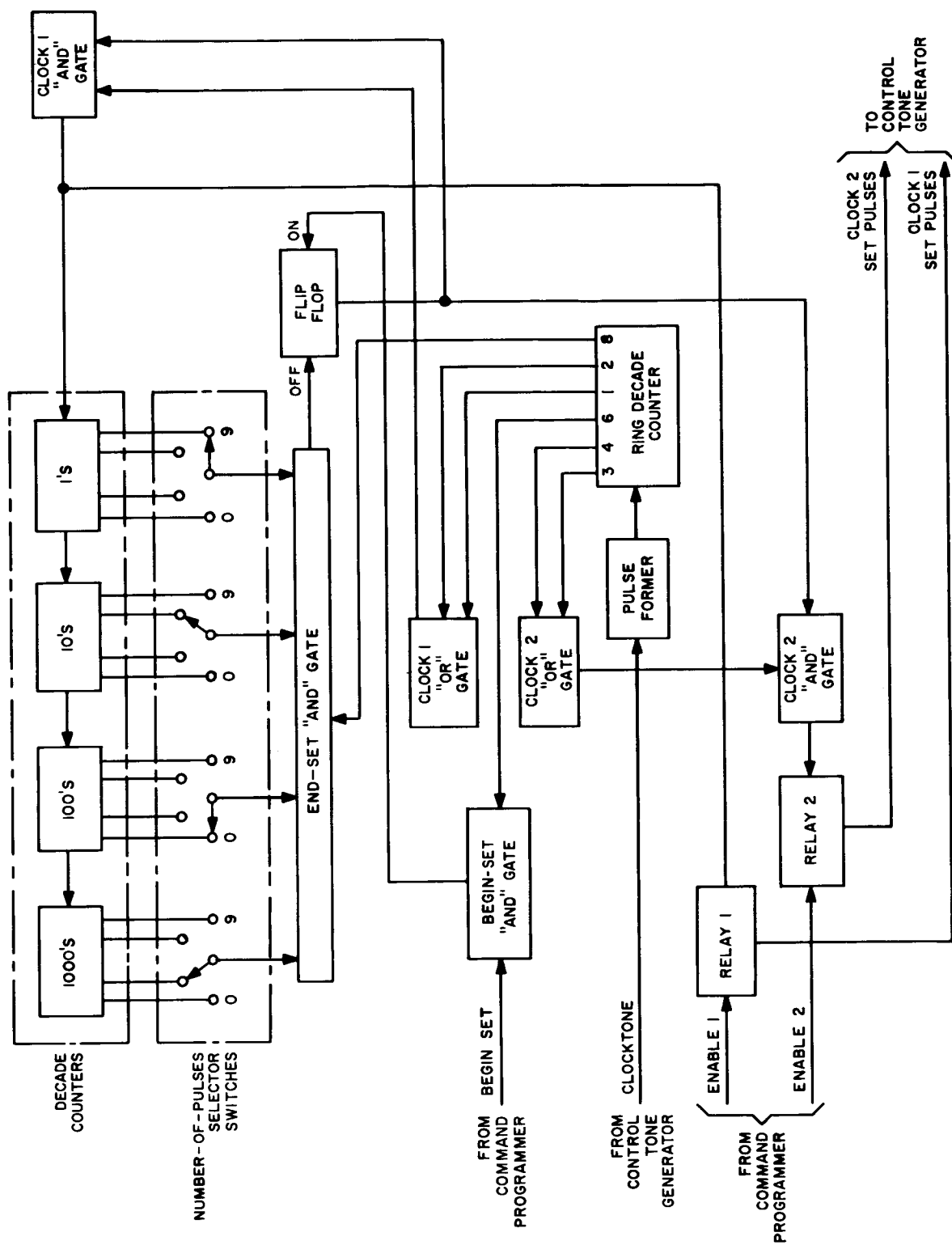
Figure 26. Remote Picture Time Set, Front View

counter. Rather than duplicate design efforts, it was decided to purchase the required counters. (Burroughs DC-106A counter decades with Nixie readout were selected for the TIROS application.)

2. Functional Description

Figure 27 is the block diagram of the remote picture time set. The number of pulses required for setting the clock is computed at the NASA TIROS Technical Control Center and is teletyped to the various ground stations. This pulse information is set up on the number-of-pulses selector switches located on the front panel of the remote picture time set.

The wave-shape of the clock tone from the control tone generator is squared-off by the pulse forming circuit and the tone then applied to the decade counter. The counter divides the clock tone frequency by ten, and provides ten pulse outputs. Each pulse output has a repetition rate equal to $1/10$ of the clock tone frequency and each pulse is displaced from the preceding pulse by the period of the control tone. That is, pulse 1 ends as pulse 2 begins, pulse 3 begins as pulse 2 ends. Only six of the ten pulses are used; namely, pulses 1, 2, 3, 4, 6, and 8.



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Figure 27. Remote Picture Time Set, Block Diagram

Output pulses 1 and 2, and 3 and 4 are combined by their associated OR gates to provide two double-width pulses. The output of the clock 1 OR gate is applied to the clock 1 AND gate; the output of the clock 2 OR gate is applied to the clock 2 AND gate. Output pulses 6 and 8 are applied to the begin-set and end-set AND gates respectively.

When a begin-set signal is received from the command programmer, the pulse-6 outputs of the ring counter are applied to the flip-flop. The first pulse-6 sets the flip-flop to ON where it remains until an off signal is received from the end-set AND gate. So long as the flip-flop is set to ON, the clock 1 and clock 2 AND gates pass the clock 1 and 2 set pulses to their associated control relays. Enable signals from the command programmer determine whether one or both sets of clock-set pulses will be sent to the control tone generator. In addition to being applied to the clock 1 control relay, the output of the clock 1 AND gate is applied to the "1's" counter; each set pulse advances the counter one step. Every tenth step of the "1's" counter is carried over to the "10's" counter. Similarly, every tenth step of the "10's" counter to the "100's" counter and every tenth of the "100's" counter is carried to the "1000's" counter. When the decade counters have advanced to the pulse set-up on the number-of-pulses selector switch, all inputs are present at the end-set AND gate and an off signal is applied to the flip-flop, setting it to OFF. As a result, the clock 1 and 2 AND gates are disabled, terminating the generation of the clock-set pulses. A reset circuit, not shown on the block diagram, permits reset of the decade counters at the conclusion of each clock-set sequence. Figure 28[§] is the schematic diagram of the remote picture time set.

C. GROUND-BASED ANTENNAS

1. Introduction

The sites selected for the primary (CDA) ground stations were already equipped with a TLM-18 high-gain, 60-foot, parabolic reflector antenna for receiving TV picture data on 235.00 megacycles. A later-design and less costly antenna (described later in this section) was installed at the secondary (Princeton) CDA station. Initially, it was planned to use Radiquad antennas at the ground station for transmission of the 138.06 megacycle satellite-command signals, and reception of the 108.00 and 108.03 megacycle satellite beacons. However, the antenna gain at 108 megacycles was considered marginal, and an evaluation of the mechanical structure by RCA-AED revealed that this antenna was not mechanically designed to withstand the environmental forces expected at the antenna sites. Consequently, other types of antennas were used at the primary ground stations to replace the Radiquad. These are described in succeeding paragraphs relating to the specific ground station.

2. Fort Monmouth and Kaena Point

The antenna and tracking systems at the primary CDA stations, Kaena Point, Hawaii and Fort Monmouth, New Jersey, were not part of the ground equipment built by RCA. The Kaena Point antenna was part of an existing facility operated by Lockheed; the Fort Monmouth antenna was also part of an existing facility, which was operated by the

[§] This illustration is printed on a fold-out page located at rear of Section IV.

SECTION IV

Signal Corps. The tracking antenna used at each of the above sites is a parabolic reflector type, 60-feet in diameter, and has an automatic tracking capability at 235-megacycles. Gain of the antenna in the 235-megacycle band is 29 db. Elements for the reception of the 108-megacycle band are in the same reflector and contain both horizontal and vertical components with appropriate feeds to permit reception in polarization diversity. Gain of the 108-megacycle elements is 23 db.

The Fort Monmouth command transmitter antenna, a circularly-polarized Yagi with a gain of 12 db in the 130-megacycle band, was mounted on the reflector dish of the receiving antenna. The Kaena Point command transmitter antenna, a 10-db gain helix, was mounted on a radar dish located about two miles from the 60-foot-antenna. The radar dish was slaved to the 60-foot antenna.

3. Princeton, New Jersey

a. General

The antenna system, which was used as part of the RCA back-up ground station installation at Princeton, was an experimental array of the cigar type. Use of the cigar array represented a distinct departure from the usual technique of obtaining large gains with parabolic-dish signal collectors. This type of array provided the advantage of being considerably lighter and far less expensive than a dish of comparable gain. The major disadvantage of the cigar array is that any given design is essentially a one frequency-band device. Because of this, the cigar array must be redesigned and re-fabricated whenever a change in frequency band is required.

The antenna system designed for the Princeton ground station was comprised of three separate array combinations; one array for each of the three TIROS frequency bands. The 138-Mc array consisted of a single cigar element; that is, one end-fire disk-rod combination. The 108-Mc array consisted of four cigar elements, while the 235-Mc array consisted of eight cigar elements. The Princeton antenna system is shown in Figure 29; the arrangement of the arrays is shown in Figure 30.

The 138-Mc array had two linear, orthogonally related driving elements; one array was disposed 45 degrees from horizontal, and the other was disposed 135 degrees from horizontal. A separate feed was supplied for each of the two elements. Only linear polarization was used for commanding TIROS from this location; no attempt was made to combine the feeds for the purpose of obtaining circular polarization. The measured gain and beam-width were 10 db and 22 degrees, respectively.

Each cigar element of the 8-element 235-Mc array has two orthogonally related driving elements, disposed 0 and 90 degrees from the horizontal, for obtaining separate horizontal and vertical components. The feeds of all corresponding driving elements were connected in parallel and in phase to achieve the maximum aperture dimension from the summation of the individual array outputs. Two 24-db preamplifiers, one for each of the orthogonally related outputs, were mounted on the antenna pedestal. Coaxial lines carried the outputs of the groups to two corresponding receivers for polarization diversity operation. Measured gain and beamwidth were 22 db and 9 degrees, respectively.

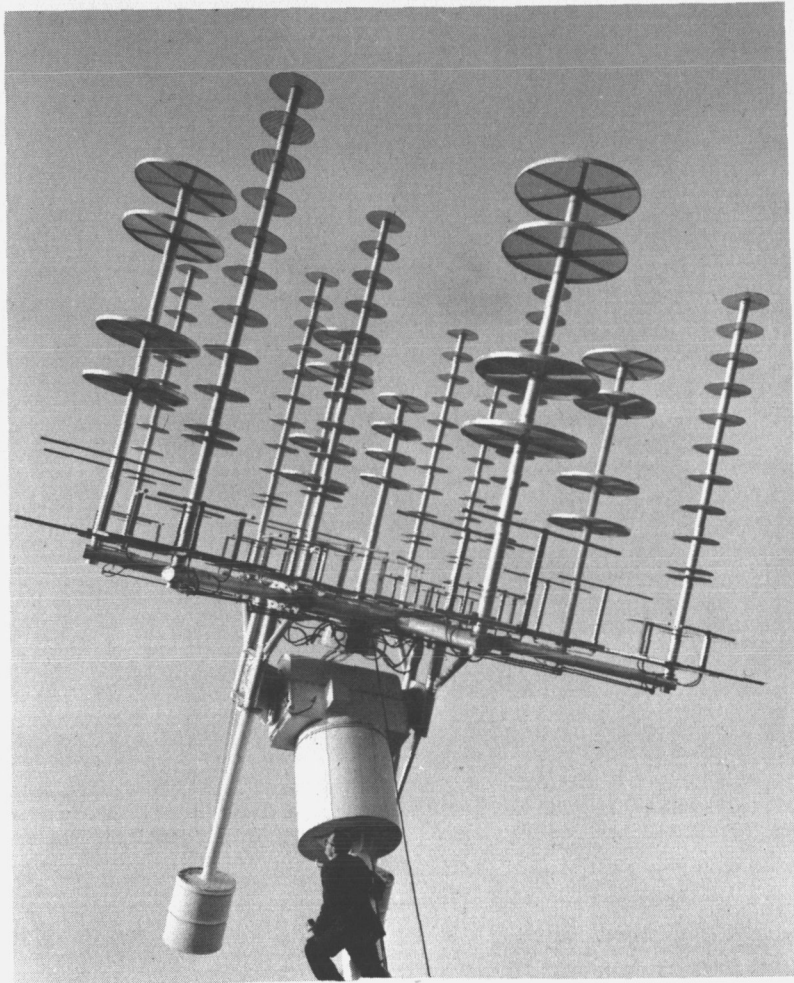


Figure 29. Princeton Antenna System

The cigar elements of the 108-Mc array had driving elements for only one polarization; however, the elements were adjustable to any angle, so that any polarization could be chosen for use. Although selection of polarization was provided, all operation was with the elements arranged for horizontal polarization to minimize ground reflection errors in the automatic tracking operation. The gain and beamwidth of this array were 18 db and 16 degrees, respectively.

In the overall design of this antenna system, the automatic tracking feature was planned to operate in the 108-Mc band. For this reason the feed-line system of the 108-Mc array differs from those of the other two arrays.

The phase-monopulse principle was used for developing the tracking-error signal. The outputs from each driven element were fed to two hybrid rings (Figure 31) in order to derive two difference signals, which were proportional to azimuth and elevation errors, and a third signal, which was the sum of the outputs of the four

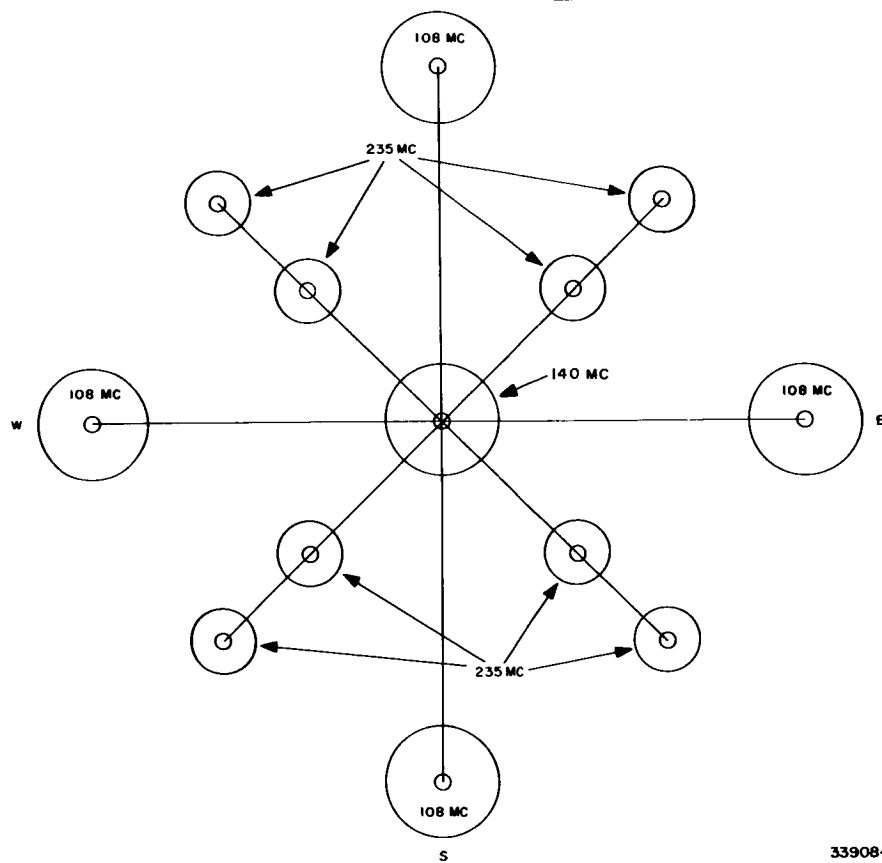


Figure 30. Princeton Antenna Arrangement

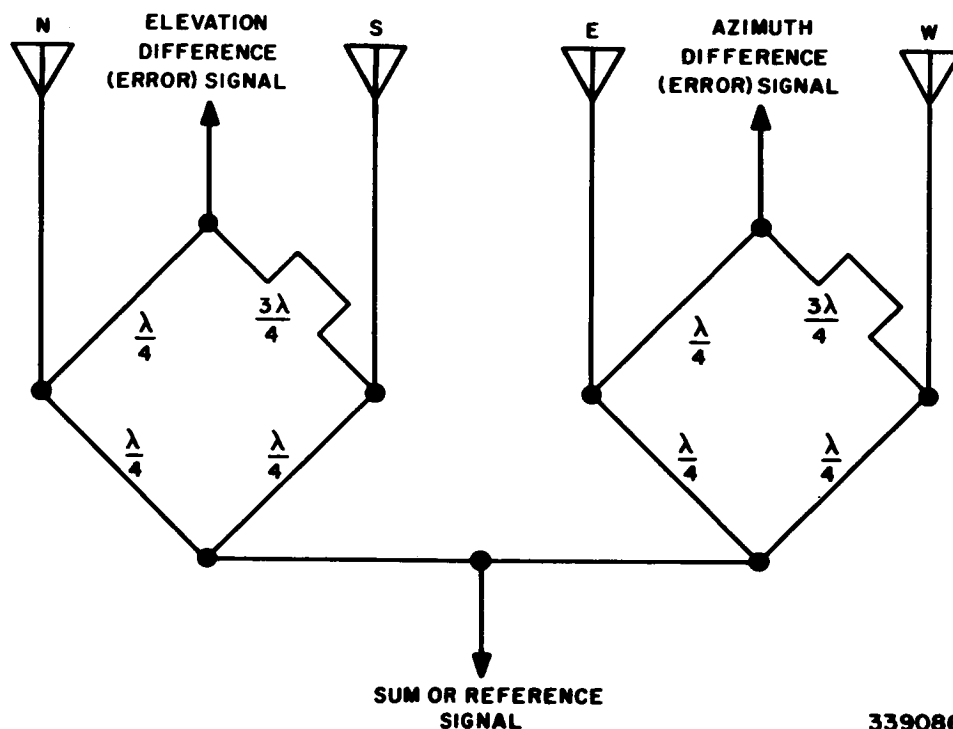
driven elements. The sum signal was used both as a reference signal for the azimuth and elevation difference information as well as for the recovery of the telemetry data modulating the beacon carriers.

b. Functional Description

Basically, the cigar antenna is a modified yagi, or end-fire array. The gain of a conventional end-fire array is proportional to its length up to the point at which gain no longer increases with length. If, however, the phase velocity along the array is modulated in a particular manner, the length-versus-gain limit can be extended and gains well above those obtainable with the conventional array can be achieved. The phase-velocity modulation is achieved by modulating* the lengths and spacings of the parasitic dipole elements along the array. In the cigar antenna the parasitic elements are disks arranged along a metal rod.

The use of disks instead of linear elements provides complete freedom in choice of the polarization plane. For example, crossed dipoles may be used as a driven element, either for polarization diversity or with quadrature feed to achieve circular polarization.

* That is, by assigning somewhat different dimensions to each length and spacing in accordance with the established design.



339086

Figure 31. Monopulse Receiving System Functional Diagram

Automatic tracking is accomplished by a phase monopulse system. The simple equations for the system are obtained by considering a plane wave approaching two antennas whose outputs are combined in a hybrid to produce a sum and a difference output. (See Appendix B.) These sum and difference outputs are then combined in a phase detector which yields a d-c error voltage. The magnitude of this error voltage is proportional to the angle between the line joining the two antennas and the projection of the approaching wave front on the plane of the antennas. The sense of the error voltage corresponds to the sign of the angle. This signal, when further amplified, drives the servomechanisms which keep the antenna on course.

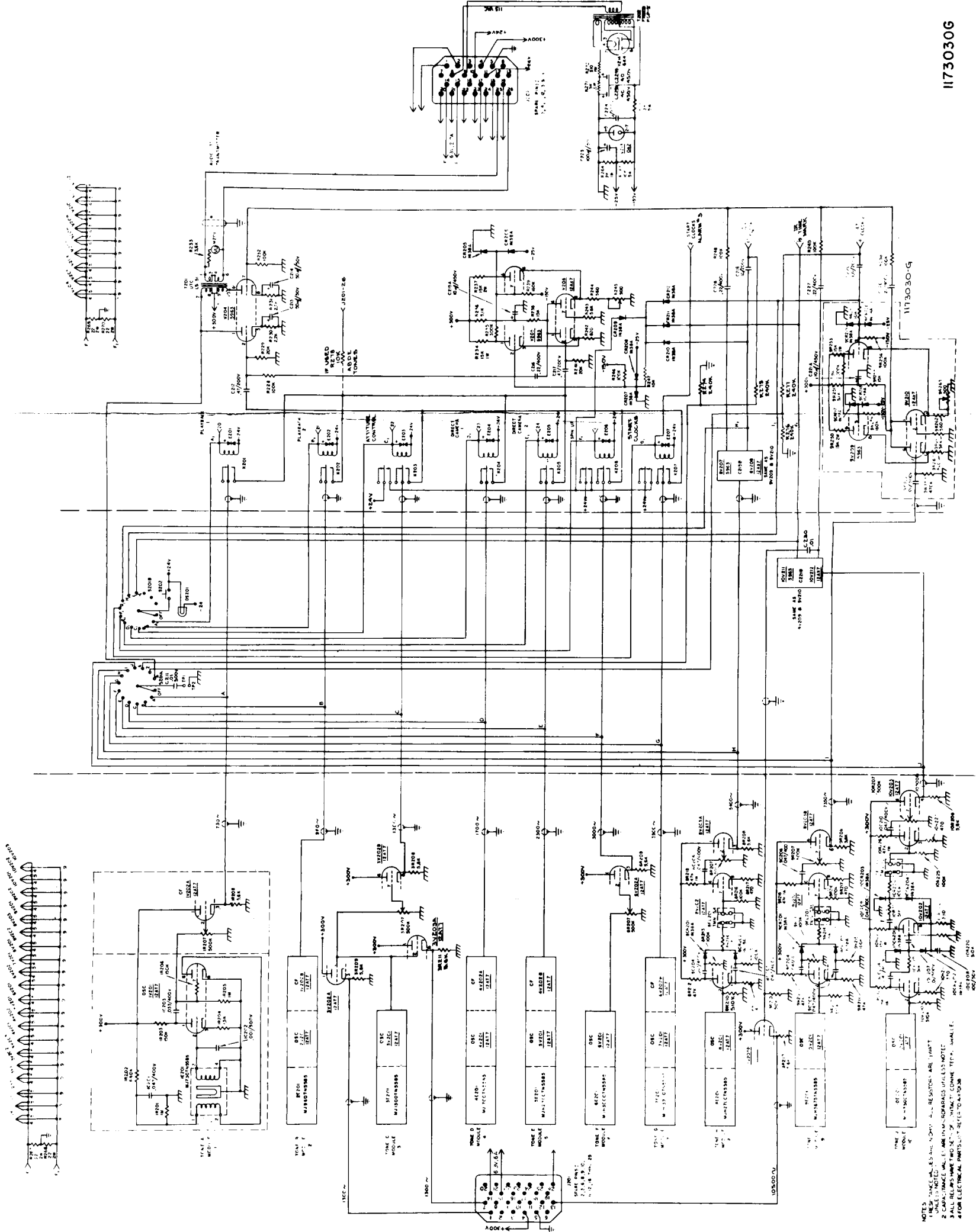
Due to the two degrees of freedom, three outputs from the hybrid are required; a sum or reference signal, an azimuth error signal, and an elevation error signal. These three outputs are amplified by three receivers that are fed by the same local oscillator. The gain of each receiver is controlled by the same AGC. The use of AGC makes the error outputs dependent on angular error and independent of antenna signal strength.

The antenna system tracks on the satellite's beacon transmitter. The hybrids yielding reference and error signals are located on the antenna itself. Three coaxial cables of approximately the same length bring these signals to three Tape-Tone 108-Mc frequency converters which are all fed from the same 93.6-Mc local oscillator.

SECTION IV

The 14.4-Mc outputs from the Tape-Tone converters are then fed to three R-390A receivers. Two local oscillators, at 2 Mc and 17 Mc, are used in the R-390A receivers. These two local oscillators must be kept phase coherent. To implement this, the sum-channel oscillator outputs are put through buffer amplifiers which feed all three receivers. The AGC circuits of all three receivers are tied together in the diversity mode so that the reference AGC controls the gain of all the receivers.

The 455-kc output of the sum receiver is amplified to drive two phase detectors. Each error signal is amplified at 455 kc and fed to its corresponding phase detector after being phase shifted by 90 degrees. Since the General Bronze Servo is built to operate on a 60-cycle error signal, the reference signal is gated at a 60-cycle rate. The d-c error then becomes a 60-cycle error whose amplitude is proportional to the error amplitude and whose phase (being either in phase with the gating signal or 180 degrees out-of-phase with it) indicates the sense of the error. These 60-cycle gated errors are then passed through two 60-cycle bandpass amplifiers which filter out harmonics of 60 cycles as well as extraneous noise introduced due to the much wider bandpass of the receiver i-f amplifiers.



11730306

Figure 25. Control Tone Generator, Schematic Diagram



1176110K

Figure 28. Remote Picture Time Set, Schematic Diagram

SECTION V. STANDARD PERFORMANCE-EVALUATION TEST PHILOSOPHY

A. REQUIREMENT

A standard performance-evaluation test (RCA-AED Test Specification SP-T1-200) (see Appendix C) was established to give a comparative value of the flight satellite's performance, rather than to prove compatibility, between the flight satellite and the associated ground equipment. The results of these tests indicated whether any change in performance of the satellite's components was due to environmental stress or aging. (Prototypes T-1 and T-2 have proved the compatibility between the satellite and ground equipment).

The sequence of these electrical calibration tests was performed before and after each environmental test and before shipment of the satellites to the launch site. A record of each of these tests accompanied the satellite during each subsequent activity. The test included the following measurements of proper operation.

- Test I. Command Receiver Sensitivity and Selectivity
- Test II. Transmitter Power Output and Frequency
- Test III. Evaluation of Control Tone Filters, Control Tone Detectors, Power Control Relays, Cameras, Video Subcarrier Oscillators, Direct Mode Camera Shutter and Synchronizing Circuits
- Test IV. Evaluation of Clock Remote Timing, Tape Recorders, and Associated Tone Filters
- Test V. Sun Sensors, Horizon Scanners, Spin-Up Rocket, and Beacon Killer Command Functions

B. PROCEDURE

The electrical test varied with the requirements of the three major environmental considerations - vibration, thermal-vacuum, and acceleration. Prior to beginning any of the environmental tests the satellite was given a complete electrical test. From the data obtained, the degradation of performance could be evaluated.

The vibration phase of the environmental program, because of machine capacity, was divided into several vibration runs. After setting the satellite on the vibration machine,

SECTION V

[REDACTED]

a Go, No-Go test was performed. This Go, No-Go test consisted of a complete telemetry run in each of the four major modes of operation. A visual check with each function of the satellite was then made and recorded in the log books (as satisfactory or unsatisfactory). At the completion of each portion of the vibration test, a similar Go, No-Go test was performed and all modes of operation rechecked. Similar tests were also repeated prior to and after each phase of this operation. During the actual vibration tests the satellite was in a stand-by condition such as would be encountered during the launch. For this portion of the test, the beacon output was recorded on Sanborn recorders from the outputs of the beacon receivers in the ground station.

The thermal phase of the environmental tests required more extensive testing during its entirety. Because the space environment of the satellite would put it on a 100-minute thermal cycle, tests were run every two hours. During actual operating conditions, it was expected that the satellite would be in the sun approximately 75% of the time. To simulate this condition, a battery charger was cycled at 1-1/2 hours on a 1/2 hour off. During the on portion of the cycle, the batteries were charged at a 1.2 ampere rate and were so programmed during the two hour tests as to provide a balanced power program for the batteries. Test patterns were mounted in front of each of the two cameras such that degradation of performance could be observed at all times. The data recorded included a complete set of polaroid picture data of the long persistence monitor in the ground station and the measurement of the clock-delay time for the remote cycle. Photographs were taken during both Direct and Remote modes. In this manner, the video performance could be monitored constantly. The battery current was constantly monitored. During the test, battery voltages were measured 5 minutes before the end of the no-charge cycle and 5 minutes after the start of the charge cycle to establish battery criteria and operability. Once each day during the entire thermal vacuum period a complete set of 35-mm pictures was taken of the short persistence monitor and the standard ground station camera.

Because the two primary temperatures of the thermal-vacuum test were 0° and 50°C, a complete standard performance-evaluation test (electrical calibration) was performed at these temperatures. The conditions that were measured included the command receiver sensitivity and selectivity, and transmitter power output and frequency (although the total power output could not be measured). Special attention was paid to various on and off delay times, the appearance of horizontal sync in both direct camera modes and the remote camera modes, resolution, and extraneous noises. The spin-up rocket switch and the beacon kill function were programmed, and the horizon scanner was checked. The sun-angle sensors, because of inaccessibility, could not be checked.

For the acceleration check it was necessary to move the satellite to a remote location, where test equipment was not available for a complete electrical test. Prior to shipment for these tests, a complete standard performance test was conducted on the satellite and, during the test, the audio tone of the beacons was monitored. At the completion of the acceleration tests, when the satellite was returned to RCA, a second complete standard performance test was performed.

C. TYPICAL TEST RESULTS

Typical standard performance-evaluation test results are shown in the following log sheet.

LOG SHEET**STANDARD TEST RESULTS (SP-T1-200)****TIROS SATELLITE**

Satellite Model: Typical

Test Sequence Number: Typical

Test Results:**Test 1. Command receiver sensitivity and selectivity**

Generator on command frequency

Minimum signal required for command

Direct camera one	0.55	microvolts
Direct camera two	0.4	microvolts
Playback tape one	0.6	microvolts
Playback tape two	0.45	microvolts

Generator 10 kc below command frequency

Minimum signal required for command

Direct camera one	0.6	microvolts
Direct camera two	0.45	microvolts
Playback tape one	0.6	microvolts
Playback tape two	0.5	microvolts

Generator 10 kc above command frequency

Minimum signal required for command

Direct camera one	0.7	microvolts
Direct camera two	0.6	microvolts
Playback tape one	0.75	microvolts
Playback tape two	0.65	microvolts

SECTION V

Test 2. Transmitter Power Outputs

TV Transmitter power delivered to antennas

Transmitter 1 to N antenna	0.46	watts
S antenna	0.40	watts
E antenna	0.42	watts
W antenna	0.38	watts
Total power	1.8	watts
Frequency	235.004877	Mc/sec

Transmitter 2 to N antenna	0.47	watts
S antenna	0.46	watts
E antenna	0.44	watts
W antenna	0.42	watts
Total power	2.19	watts
Frequency	234.993657	Mc/sec

Beacon 1 output	0.025	watts	107.999974	Mc
Beacon 2 output	0.024	watts	108.027064	Mc

Test 3. Evaluation of Tone Filters and Detectors, Relays, Cameras, Video SCO's Direct Mode Shutter, and Sync Circuits

Program for Alternating Camera

Time before 1st TV Transmitter turns on: 28.2 sec

Camera System I

Time Interval Between Pictures (Both Transmitters Off)	1.7	sec
Amplitude of TV Subcarrier Out of Receiver	1.4	V
Amplitude of Sync Pulses Out of TV - FM Demod	0.5	V
Amplitude of Video Signal Out of TV - FM Demod W/1200 ft/candle	1.0	V
% of Full Picture Width Off Center	0	
Horizontal Sync Frequency	250	~

Camera System II

Time Interval Between Pictures (Both Transmitters Off)	1.8	sec
Amplitude of TV Subcarrier Out of Receiver	1.4	V
Amplitude of Sync Pulses Out of TV - FM Demod W/1200 ft/candle	0.5	V
Amplitude of Video Signal Out of TV - FM Demod	1.0	V
% of Full Picture Width Off Center	0	
Horizontal Sync Frequency	250	~

Make hard copy prints of 10 pictures on 35 mm and attach to record.
Make 2 polaroid pictures.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099
1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	

Camera II

P-to-P noise on sync tips (during one Horizontal line)	0.05 V
P-to-P value of Horizontal Sync Pulses from FM Demod	0.5 V
Appearance of H-Sync:	slight ringing on leading edge

Camera II Frequency and % Extraneous Pulses: 0.50 cycles and clean

Program manually for Playback I and set in 8970 pulses to both clocks.

Command playback LN (Record, identify, and attach all playback pictures to this record).

During playback time in which lens was capped:

[REDACTED]

SECTION V

During playback of recorded pictures:

Sync amplitude	0.5
Video amplitude	1.0
D-C level of sync tips start of playback	+0.1 V
D-C level of sync near middle of playback	0
D-C level of sync near end of playback	-0.1 V

Command Playback 2N

Elapsed time before transmitter 2 turns on	28.0
Amplitude of video subcarrier out of TV receiver	1.4 V
Horizontal sync frequency	250 ~
Time between pictures (approx.)	1 sec

During playback of tape when lens was capped

Peak-to-peak sync amplitude	0.5
Peak-to-peak noise on sync tips (% of sync)	10
Peak-to-peak noise on horizontal line (% of sync)	15

During playback of recorded pictures

Sync amplitude	0.5 V
Video amplitude	1.0 V
D-C level of sync tips near start of playback	+0.1 V
D-C level of sync tips near middle of playback	0
D-C level of sync tips near end of playback	-0.1 V

Test 5. Sun Sensors, Horizon Scanner, Spin-Up Rocket and Beacon Killer
Command Function

Record photographically 10 kc bursts from each sun angle sensor.

Sun Sensor	Burst Amplitude	Burst Duration
1	0.6 V	60 milliseconds
2	0.6	130
3	0.6	220
4	0.6	220
5	0.6	130
6	0.6	130
7	0.6	60
8	0.6	220
9	0.6	60

Record photographically 3 kc tone burst from horizon scanner

Reading Number	Burst Amplitude	Burst Duration
All readings	8 V P-P	110 msec

Spin-Up Rocket Test

Rocket Numbers	Time of Spin-Up	Initiation of Tone	Rocket Firing Time	Firing Voltage at Rocket Fixture
1				
2	O.K.	<u>✓</u>	6.2 sec	28.6 V on all (unarmed)

Time of beacon turn-off 20.5 for both

Time of beacon turn-on 28.1 for both

The results of the tests are shown in the following figures: (1) Figures 32 and 33 (test patterns of camera system I and II, direct mode and playback), (2) Figure 34 (amplitude of sync pulses out of TV-FM demodulator), (3) Figure 35 (amplitude of video signal out of TV-FM demodulator W/1200 ft/candles), (4) Figure 36 (sun angle pulses with varying durations of a 10-kc burst), and (5) Figure 37 (horizon scanner output).

Although telemetry data was not required during this test, sample telemetry data was recorded as shown in Figures 38 and 39.

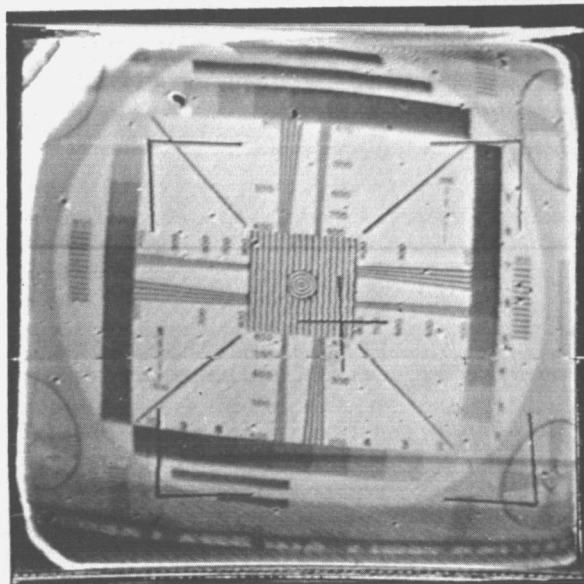
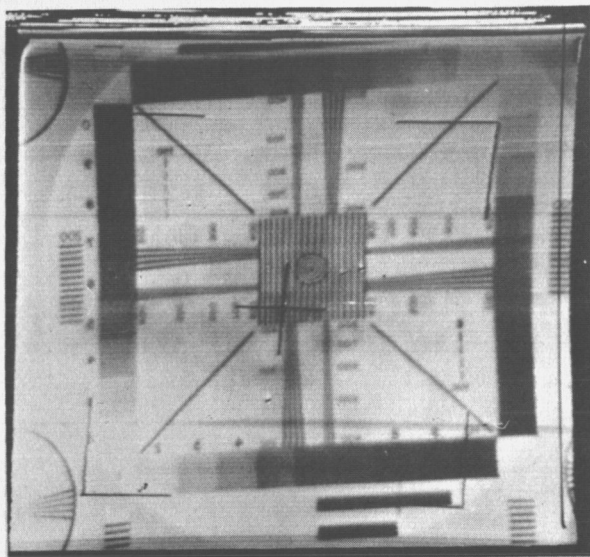
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Figure 32. Test Patterns of Camera Systems I and II, Direct Mode

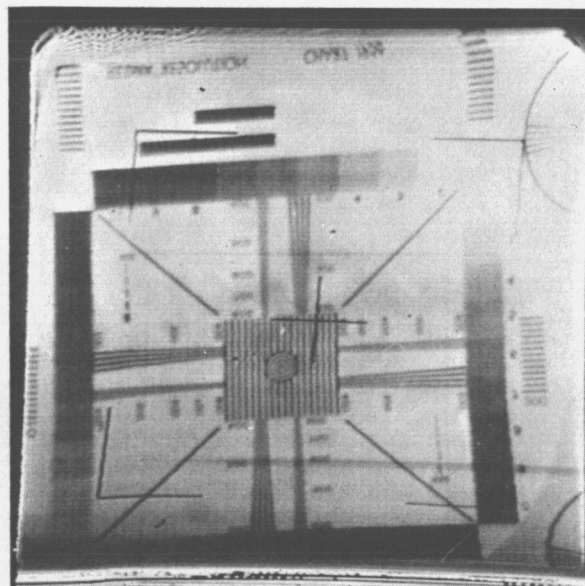
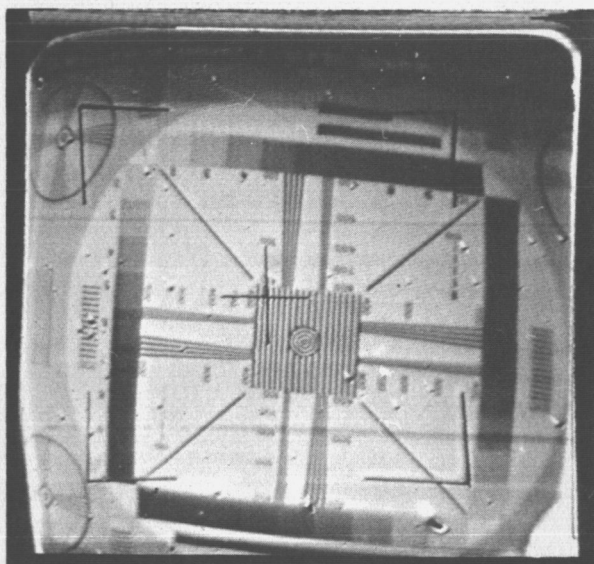
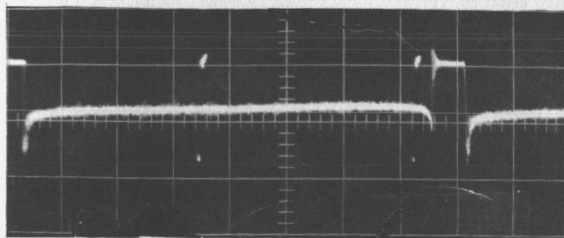
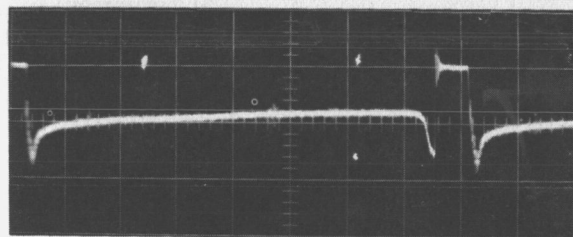


Figure 33. Test Patterns of Camera Systems I and II, Playback

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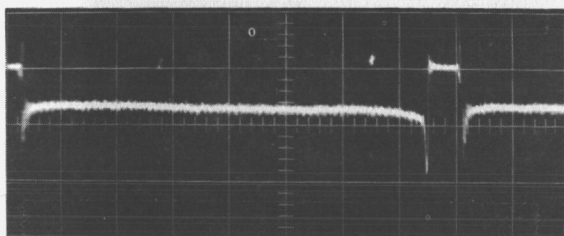


Camera System I

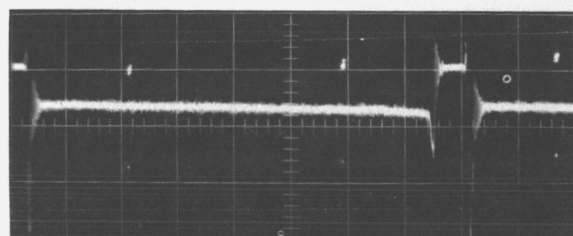


Camera System II

Direct Mode



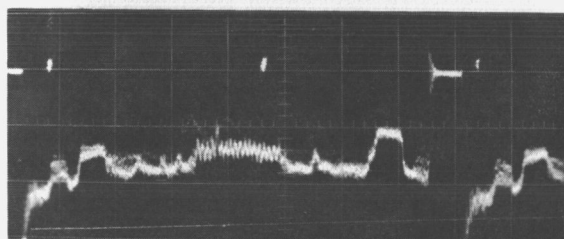
Camera System I



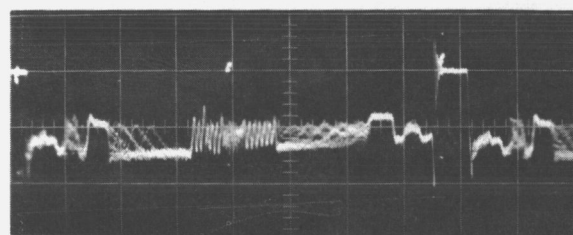
Camera System II

Playback

Figure 34. Amplitude of Sync Pulses Out of TV-FM Demodulator: Deflection;
Vertical 0.5v/cm; Horizontal 500 μ sec/cm

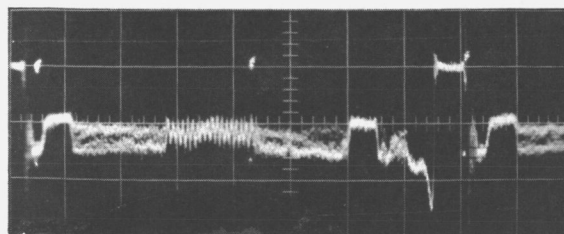


Camera System I

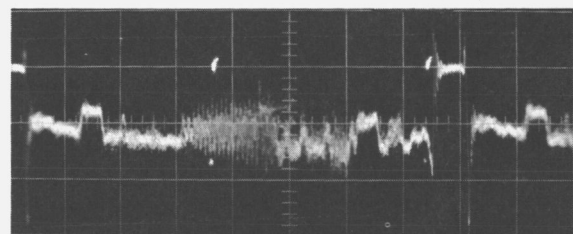


Camera System II

Direct Mode



Camera System I

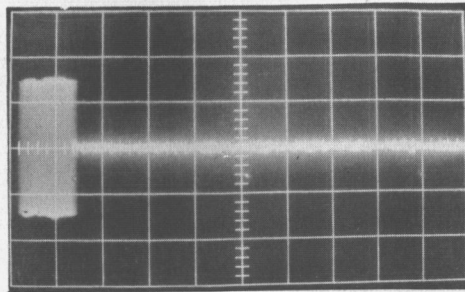


Camera System II

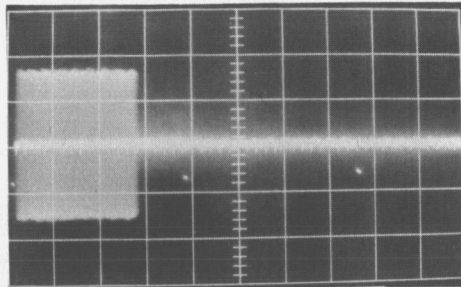
Playback

Figure 35. Amplitude of Video Signal Out of TV-FM Demodulator with 1200
ft/candles: Deflection; Vertical 0.5v/cm; Horizontal 500 μ sec/cm

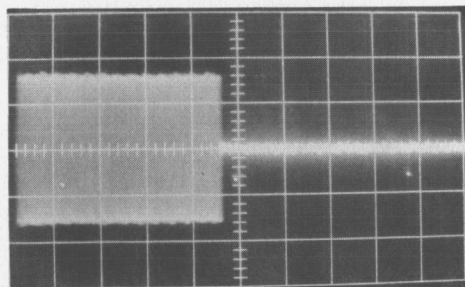
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Burst Duration 60 Milliseconds



Burst Duration 130 Milliseconds



Burst Duration 220 Milliseconds

Figure 36. Sun Angle Pulses (10-kc Burst): Deflection; Vertical 0.5v/cm; Horizontal 50 milliseconds/cm

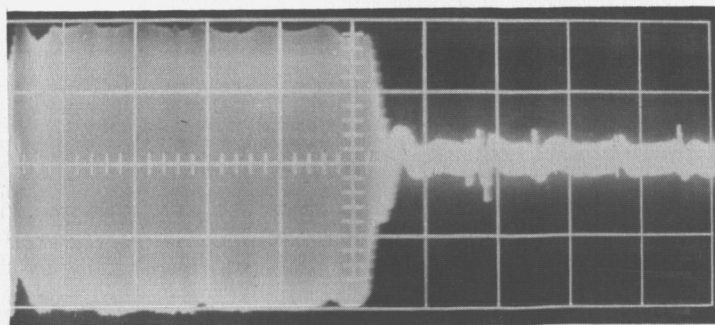


Figure 37. Horizon Scanner Output (3-kc Tone Burst): Deflection; Vertical 2v/cm; Horizontal 20 μ sec/cm

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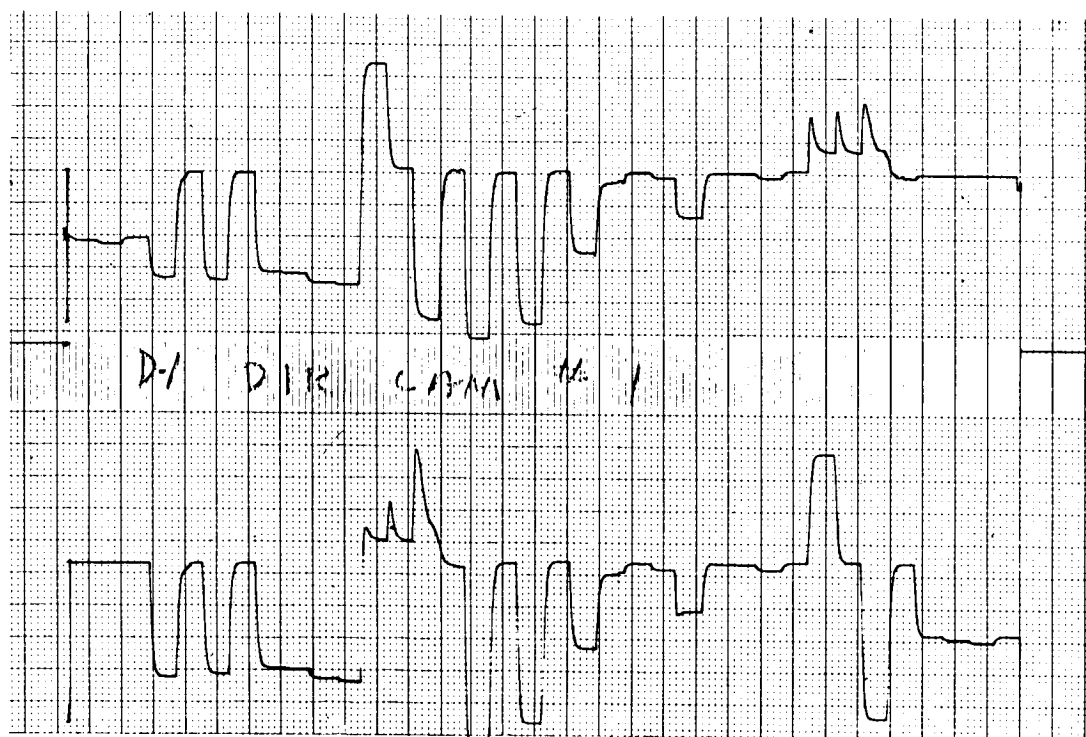


Figure 38. Telemetered Data of Camera Systems I and II, Direct Mode

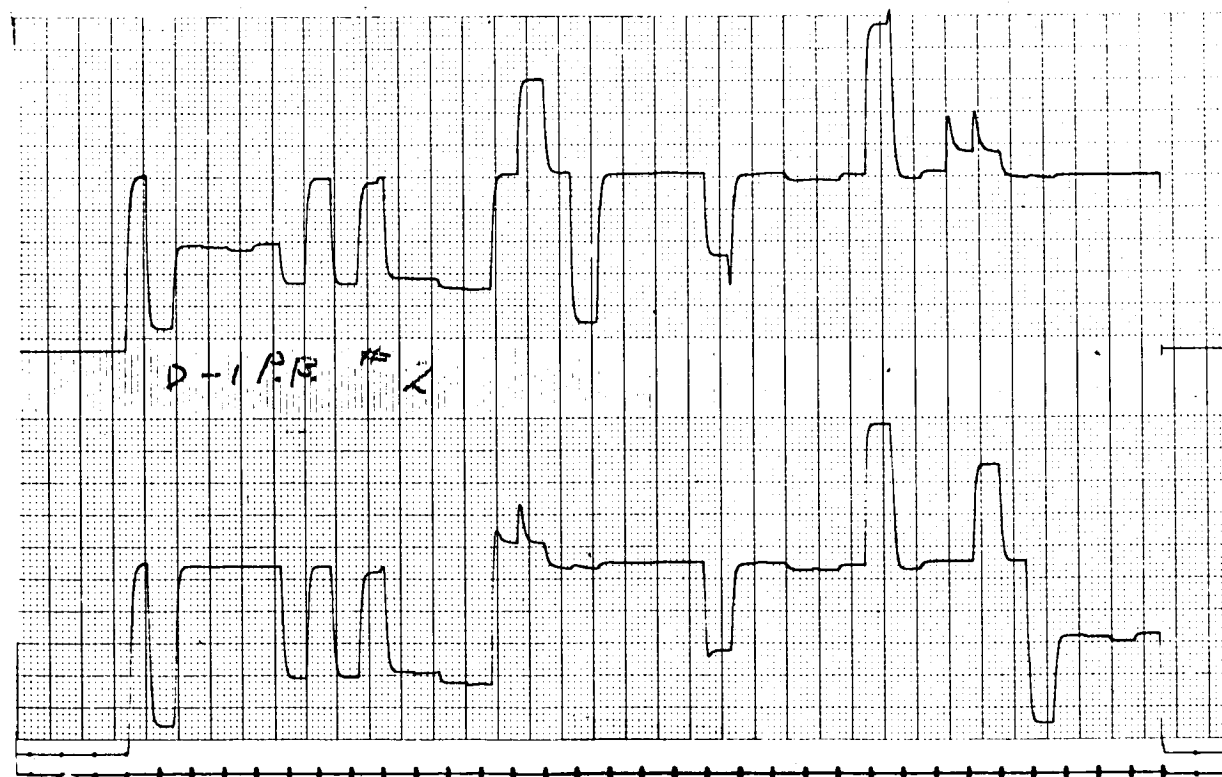
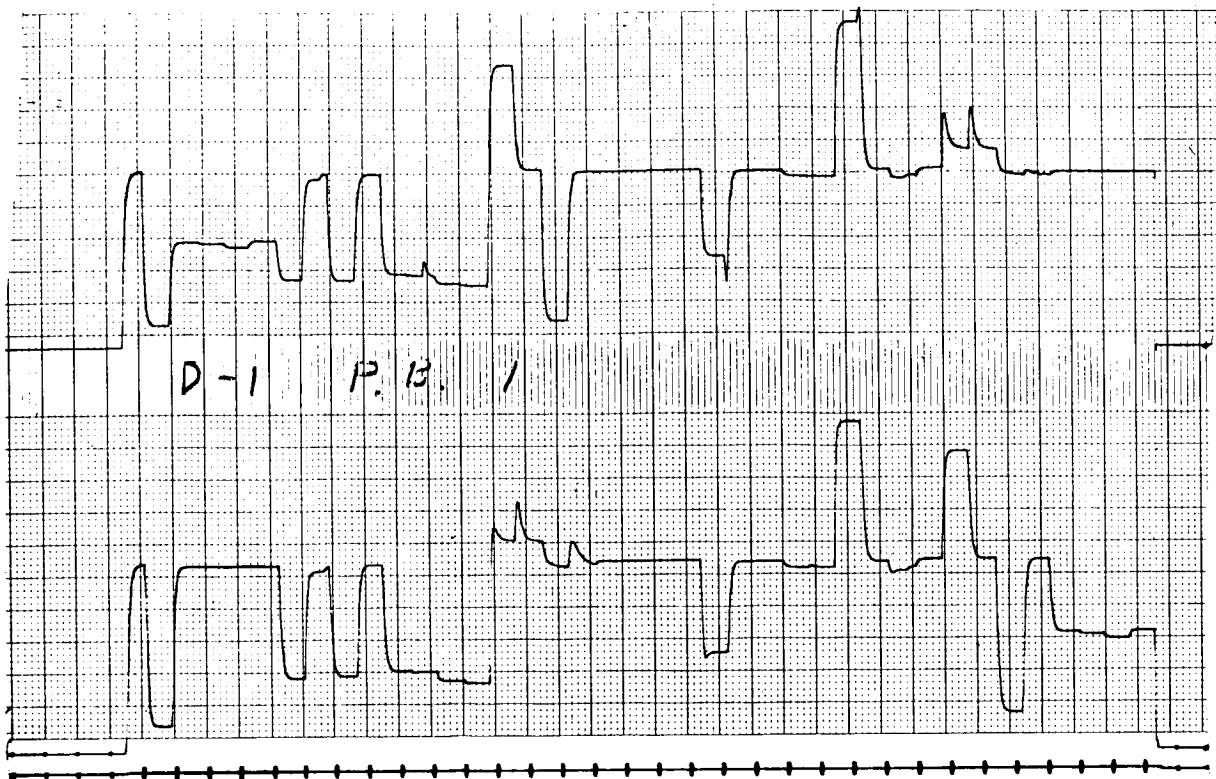


Figure 39. Telemetered Data of Camera Systems I and II, Playback

SECTION VI. OPERATIONAL MODES AND PROCEDURES

A. PHILOSOPHY OF SATELLITE CONTROL

The TIROS I system incorporated a highly-sophisticated satellite control system (for the state of the satellite art at that time). Operation of the satellite instrumentation and its dynamics control devices were controllable from the ground Command and Data Acquisition (CDA) stations, both for the time and duration of operation, and the sequence. Instrumentation could be programmed for a direct response (i. e. , picture-taking and immediate transmission to the CDA station) or for a delayed response (i. e. , picture-taking at some location out of control-range of the ground station; and tape storage of the picture for later transmission to the CDA station). Also, direct picture transmission and transmission of stored data could be commanded, in a controlled sequence. Auxiliary data, such as the sun angle and telemetered voltages and temperatures, were transmitted automatically in a preselected sequence.

Normally, a command program was set into the programmer, or programmers (a duplicate programmer was provided for either a subsequent-pass program or a redundant, back-up program), and this was sent automatically at high speed when the satellite came within communication range. Because of the relatively short time of contact, within which it was necessary to both command and "read out" the satellite, human manipulation of the controls (i. e. , manual operation) was considered to be too slow and too liable to error. Therefore, the provision was made for a more leisurely setting-up of a program, and verification of control settings, for satellite control during a pass. However, provision was included for manual and individual control of satellite function if this became necessary. This feature was used a number of times during the operational life of TIROS I.

Programming of the satellite for any pass required an analysis of information returned by the satellite from previous passes, plus information as to the geographical coverage desired for that pass. This information was sent, by the various supporting facilities and cooperating agencies, to NASA's TIROS Technical Control, where the satellite control program was made up. The program was sent by teletype (code), through NASA's Space Control Center, to the pertinent CDA station, where the operator set it into the programmer. Details of the programming design and functioning are included in the Instruction and Operating Handbook for the TIROS I Meteorological Satellite System.

The operational modes and manpower requirements of a CDA station are discussed further in this section.

B. OPERATIONAL MODES**1. Satellite TV Picture-Taking Modes**

Two automatically-sequenced modes of TV picture-taking were possible. The first: Direct Picture transmission, was used when the satellite was within range of a CDA station. In this mode, pictures were transmitted directly from the satellite's cameras to the CDA station, bypassing the satellite's tape recorders. The second: Tape Playback, was used when pictures were to be taken outside the communication range of the CDA stations. This involved storing the pictures on magnetic tape and transmitting them on command, when the satellite came within range of a CDA station.

The direct picture mode provided an option of two sequences: Direct Camera Sequence I, which, if programmed, transmitted direct photography before tape playback of remote pictures; and Direct Camera Sequence II, which, if programmed, transmitted direct pictures after remote picture playback. Both Direct Camera sequences (I and II) could have been programmed to occur during a given pass of the satellite. In this case, direct pictures would have been taken both before and after tape playback occurred.

It was desirable that tape playback of remote pictures occur at that portion of the satellite's pass which was closest to the overhead position, and therefore, more favorable for receipt of signals by the CDA stations. Consequently, the transmission of a direct camera sequence on either side of the playback sequence took full advantage of the time available for transmission of TV pictures, without losing any of the remote photography, during the satellite's time of contact.

Programming of the satellite was performed during the time of receipt of data. Clock-set pulses could be sent simultaneously with command tones, making use of the "holes" or intervals between tones to make maximum use of the short time of satellite contact.

a. Direct Camera Sequences I

A choice of program was available for this sequence, providing additional flexibility of operation. The following selection of operating program was available:

(1) Camera System Desired

Facilities were provided to select the wide-angle camera only, the narrow-angle camera only, or alternate pictures from both cameras.

(2) Picture Interval Desired

A 10-second or a 30-second interval, between pictures, could be selected. The 30-second interval provided adequate overlapping of the wide-angle pictures to allow matching of adjacent pictures for preparation, for meteorological use, of a picture mosaic. The 10-second interval provided additional flexibility for possible experimental work or checkout of the satellite's cameras. If alternate camera operation was selected, the picture interval would be set automatically to 30 seconds.

(3) Time Duration of Sequence

The duration of satellite operation in the Direct Camera Sequence I mode could be set by means of an Elapsed Time control for a period ranging from 0.5 minute to 8.0 minutes, in 0.5-minute increments. However, if tape playback is called for during a pass, this control is set near maximum time, and the programming for start of tape playback (Alarm 2) overrides the Elapsed Time control setting.

(4) Transmitter Warm-Up

Direct Camera Sequence I could also be used for turning-on the satellite transmitter carrier for warm-up and tracking purposes when no pictures were desired.

b. Direct Camera Sequence II

If this sequence were called for by the command program, it would start automatically at the conclusion of tape playback. The choice of program was the same as for Direct Camera Sequence I.

c. Playback and Clock-Set Sequence

During this sequence, pictures recorded earlier by the satellite tape recorders were read out and transmitted to the CDA station. Again, a choice of playback program was available: (1) information from the tape recorder in Camera System No. 1; (2) information from the tape recorder in Camera System No. 2; (3) information from No. 1, then No. 2; (4) information from No. 2, then No. 1. The choice of (3) or (4) was made available to permit the camera system used last in Direct Camera Sequence I to start playback first; hereby avoiding the wait for warm-up of that system's transmitter.

Facilities were provided for preprogramming the satellite's remote picture-taking operations during the Playback and Clock-set sequence by transmitting set-clock and start-clock pulses to the satellite's clocks. The number of set-clock pulses in conjunction with the start-clock pulse determined the time when remote picture-taking would begin.

2. Telemetry Control

Each time "Direct Camera" or "Tape Playback" operation was commanded, the telemetry switch in the satellite ran through a complete cycle, modulating the beacon transmitter carrier, in sequence, with 39 monitored parameters. These were received at the CDA station on the 108-Mc beacon receivers, from which they were shunted into the telemetry readout channel.

3. Auxiliary Control Functions

a. Spin-Up Rocket Selection and Firing

The nine pairs of spin-up rockets spaced around the satellite's periphery were selected and fired by means of a solenoid-operated rotary switch. This switch was stepped

SECTION VI

to the consecutive positions by a tone-signal command from the CDA station. Firing occurred automatically upon selection of each rocket pair.

b. The Beacon Killer

The satellite's beacon transmitter operated continuously during the operational life of the satellite. However, provisions were incorporated for shutting down the beacon at the end of the satellite's useful life, to eliminate unnecessary interference in the beacon frequency band. A control tone, sent to the satellite for a specified period, turned off the beacon transmitter. It was, however, possible to reactivate the beacon, in case it was shut down inadvertently, by proper ground station command.

4. Command Programming Control Modes

The command and control subsystem of each CDA station had provisions for direct or preprogrammed operation of the satellite. The greater portion of the command program equipment was installed in duplicate, permitting two programs to be set up in advance (for two consecutive orbits), or the same program to be set-up redundantly for backup. Three modes of control were available:

a. The Automatic Mode

In this mode, the command program was pre-set, and during transmission to the satellite, each program sequence was initiated automatically by means of a master clock. This mode was the one generally used during satellite contact, since the possibility of operator error was minimized and the amount of information transmitted to the satellite during the relatively short period of contact was maximized.

b. The "Manual Start" Mode

In this mode, the command program was preset, but each program sequence was started manually, by means of a pushbutton. This mode was intended for use only during the first few satellite orbits. Once the satellite's orbit was established, the automatic mode was used.

c. The "Manual Operate" Mode

In this mode, the program was not preset, but during the satellite contact, the individual command tones initiating the satellite's functions were transmitted by manual operation of pushbuttons on the programmer. This mode of operation was useful for troubleshooting or checking individual satellite functions, and provided a means for exercising particular portions of the satellite's equipment, in the event of a malfunction.

C. CDA STATION OPERATORS

1. General

Based on the final design of the CDA station, RCA made recommendations pertaining to the number of operating personnel required, and the duties to be performed by each. These recommendations, presented in the following paragraphs, list the CDA station crew positions (and their duties at the Princeton station). The cognizant organizations at the Fort Monmouth and Kaena Point stations established the number and responsibilities of their operating personnel in accordance with the specific station arrangement and requirements. However, the over-all functions performed were essentially the same at all CDA stations.

For a detailed description of CDA station operation, refer to the operational procedures in the Instruction and Operating Handbook for the TIROS Meteorological System.

2. Proposed CDA Station Crew and Their Duties

Proper operation of the TIROS ground station, during a group of satellite passes, requires at least eight operating personnel. Each day a group of six or seven consecutive passes occurs, with relatively little time between passes. The operating personnel and their respective duties, as proposed, are listed below:

- a. The Monitor Operator checks out and maintains the TV monitor, the sun-angle computer, and the Ampex tape recorders, and performs the ground station "count-down" on this equipment (five racks).
- b. The Programmer Operator checks out and maintains the satellite programmers, the antenna programmers, and the telemetry recorder, and performs the ground station "count-down" on this equipment (four racks).
- c. and d. The Antenna Site Operators (two) check out and maintain the TV and beacon receiving equipment, the antenna control and tracking equipment, the command transmitters, and the antenna and its drive equipment.
- e. The CDA Station Coordinator coordinates the activities of the Monitor Operator, the Programmer Operator, and the Antenna Site Operators, and "keeps tabs" on the status of their equipment. He directs the CDA station "Pre-pass group count-down" before the beginning of the day's group of passes, and the "between-pass count-down" which begins immediately as the previous pass ends and continues to the beginning of the next pass in the group. He should be able, at any time, to report to the CDA Station Supervisor the current status of equipment operation and "count-down" progress. The Coordinator keeps a complete station log of each pass, including such information as (1) satellite and antenna programming data (he will paste original teletype versions into the log), (2) the telemetry record (which he will paste into the log), (3) whether this station programmed the satellite (and if so, how many clock-set pulses were transmitted, and the precise clock-start time), (4) any equipment outages, (5) the probable quantity of the received satellite data, (6) the labels and contents of the film and tapes made during this pass, (7) whether a particular data tape was degaussed to be re-used, (8) whether positive films were run off afterward, etc.

SECTION VI



f. The CDA Station Supervisor keeps in touch with the other CDA stations as well as with the other centers of operation, such as Cape Canaveral, the NASA Computing Center, etc. He handles all incoming and outgoing telephone messages, and generally "keeps tabs" on the entire TIROS program.

g. The Teletype Operator continuously monitors messages appearing on the teleprinter; those pertinent to the CDA station he reports to the CDA Station Supervisor for evaluation and action. The Teletype Operator arranges outgoing messages (originated by the Supervisor) into standard teletype message format, and transmits them directly to the intended recipient or to Space Operations Control Center in Washington, D. C. for relay to the recipient. He also files and logs all teletype messages sent and received.

h. The Photographic Processor develops and stores the exposed 35-mm film, and makes sure that at least one loaded film magazine is available to the Monitor Operator at all times. He also provides 35-mm positives for use by AED meteorologists, subject to the security regulations invoked.

APPENDIX A

DESIGN OF A LOW NOISE INPUT CIRCUIT FOR THE SATELLITE COMMAND RECEIVER

SCOPE

This appendix describes the development of the transistorized input circuit for the satellite command receiver. The main objectives were: low noise figure, rejection of the beacon frequency, and economical use of the battery power. Three receivers in parallel were to be fed from the antenna.*

INTRODUCTION

The satellite command receiver, upon command from the ground station, turns the instrumentation inside the vehicle on. The requirements for satisfactory operation are: a low noise figure, sufficient over-all gain, narrow-band selectivity, and economical use of the satellite battery power.

The receiver is a VHF superheterodyne operating on 138.06 megacycles. The intermediate frequency is 20 megacycles. The front end of the receiver determines (1) the over-all noise figure, and (2) the possibility of cross-modulation caused by relatively strong signals outside the receiver passband reaching the input stage.

The simplified block diagram of the proposed circuit is shown in Figure A-1. The bandpass filter between the antenna and the r-f stage provides sufficient selectivity to suitably attenuate all frequencies outside of the command receiver passband. The following r-f amplifier stage (using a Motorola Type 2N700 transistor) has sufficient gain to overcome the noise of the mixer. The incoming signal and crystal-controlled oscillator are heterodyned to the mixer to produce a beat frequency in the neighborhood of 20 megacycles.

* Design modification of TIROS I eliminated one command receiver, but this does not alter the validity of this analysis.

APPENDIX A

THE NOISE FIGURE 1

The over-all noise figure $F_{1,2}$ can be evaluated from Equation (A-1).

$$F_{1,2} = F_1 + \frac{F_2 - 1}{G_1} \quad (\text{A-1})$$

Where:

- F_1 = Noise figure of the r-f amplifier
- F_2 = Noise figure of the mixer
- G_1 = Available gain of the r-f amplifier

The noise figure F_2 of the mixer is given by the following expression²:

$$F_2 = L(p_D + F_{IF} - 1) \quad (\text{A-2})$$

Where:

- L = Loss of the mixer
- p_D = Noise factor of the mixer diode
- F_{IF} = Noise figure of the i-f amplifier

Using conventional diodes, the mixer loss generally is in the order of 5; the noise factor of the diode p_D is approximately 2. To evaluate F_{IF} , the test circuit shown in Figure A-2 was used.

A signal generator (Hewlett-Packard) with a 50-ohm source impedance (point A) was fed through a 40-db attenuator to a 50-ohm terminating resistor (point B). The equivalent circuit looking into the generator at point C (with the i-f amplifier disconnected) is shown in Figure A-3.

NOTE: The calibration of the signal generator included the terminating resistor at A (or the equivalent termination with the attenuator input). Therefore, the dial actually reads

$\frac{V_S}{2}$ at A or $\frac{V_S}{2(100)}$ at B. Thevenin's equivalent circuit for the generator at B (breaking up the circuit at B) is shown in Figure A-3a. $\frac{V_S}{2}$ was the actual dial reading of the signal generator.

¹Harold Goldberg, "Some Notes on Noise Figures," Proc. IRE, Oct. 1948.

²H. Behling, "Noise Figure of Microwave Receivers Using Diode Mixers," Archiv der Elektrischen Übertragung 5, 1951.

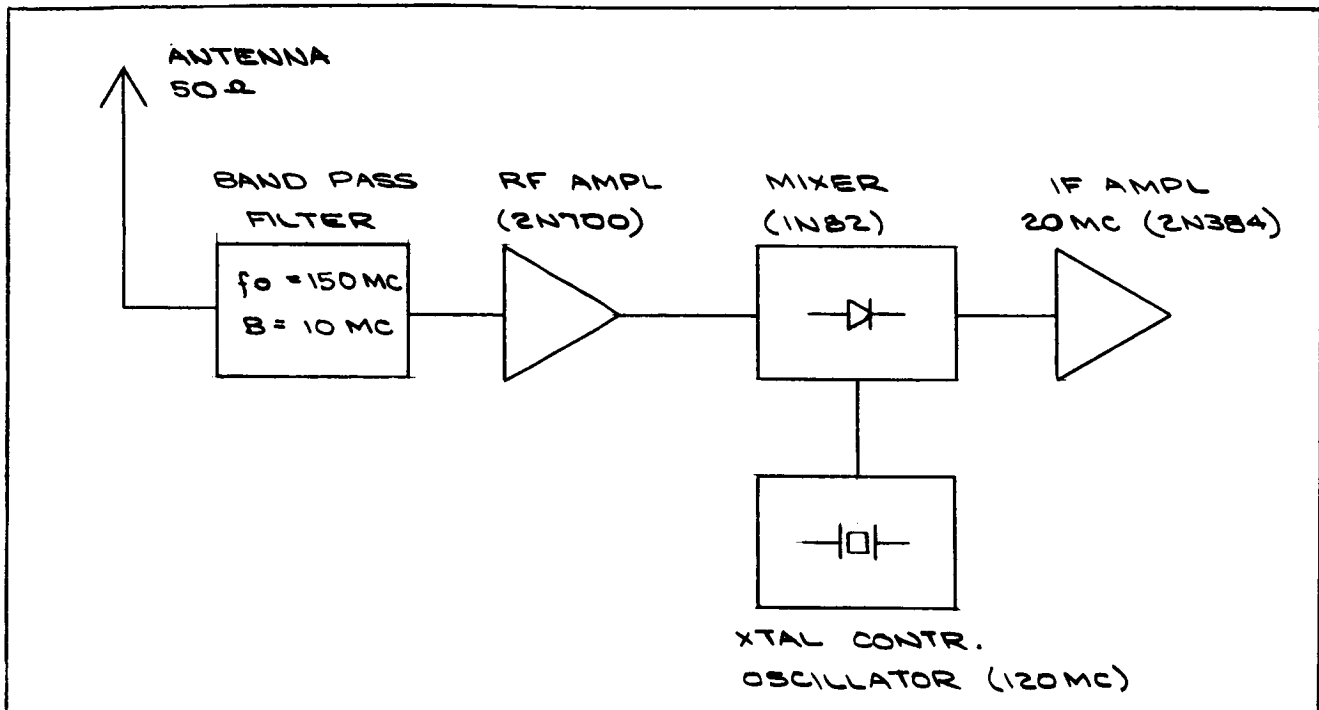


Figure A-1. Proposed Receiver Front End, Block Diagram

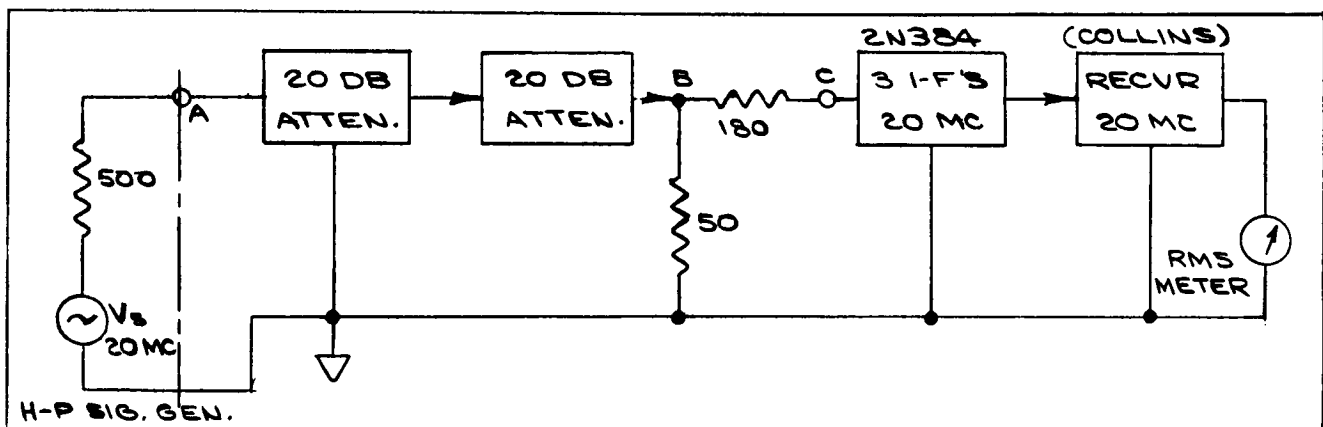


Figure A-2. Equivalent I-F Test Circuit

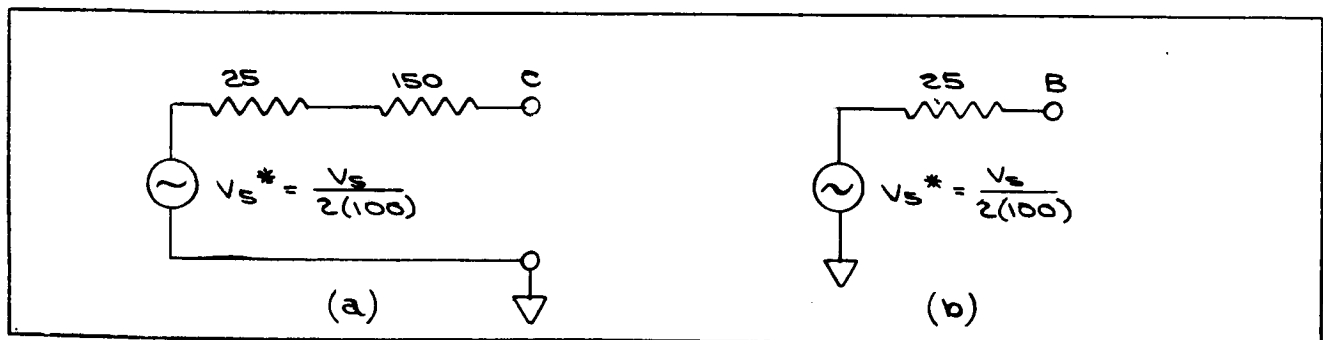


Figure A-3. Equivalent Circuit Looking into Signal Generator

APPENDIX A

The 180-ohm resistor is added in order to simulate the i-f impedance (around 200 ohms) of a conventional diode mixer circuit. Three stages of i-f amplification were considered satisfactory to overcome the noise of the Collins receiver. The output was taken from the 500-kc terminal of the receiver. The bandwidth was 4 kilocycles. The input voltage V_S necessary to double the output power was measured as 0.15 V. Then, according to the definition of the noise figure:

$$F_{IF} = \frac{V_S}{4RKT B} = \frac{2.25 \times 10^{-14}}{4(205)(4 \times 10^{-21})(4 \times 10^3)} = 1.72$$

or in db:

$$F_{IF} = 10 \log 1.72 = 2.35 \text{ db}$$

From Equation (A-2), F_2 can be calculated:

$$F_2 = 5(2 + 1.72 - 1) = 12.6, \text{ or } 11.3 \text{ db}$$

Knowing F_1 from the specifications of the 2N700 transistor (about 6 db at 150 Mc), G_1 can be determined. According to the definition of the NF of a composite network, G_1 is evaluated as follows (see Figure A-4).

The networks 1 and 2 are disconnected at B. Since the r-f impedance of the mixer is almost identical with the i-f impedance (i. e., about 200 ohms), the output impedance of the r-f amplifier R_o is matched to the input impedance of the mixer by means of the transformer T_1 (of turn ratio n). Then according to the definition of the available gain,

$$G_1 = \frac{R_1 A^2}{R_o} \left(\frac{R_2}{R_1 + R_2} \right)^2 \quad (\text{A-3})$$

$$A \left(\frac{R_2}{R_1 + R_2} \right) = \text{voltage gain of network 1 at B with 2 disconnected.}$$

$$R_o' = \text{output impedance of network 1 at B with 2 disconnected} = 200 \text{ ohms.}$$

$A \left(\frac{R_2}{R_1 + R_2} \right)$ was measured to be 5.

Then

$$G_1 = \left(\frac{50}{200} \right) 5^2 = 6.25$$

Therefore:

$$F_{1,2} = 10 \log \left(4 + \frac{12.6}{6.25} \right) = 7.8 \text{ db}$$

The measured noise figure was 7.5 db, in good agreement with the value above. The measurement was performed with Kay-Labs noise generator.

NOTE

This noise figure does not include the bandpass filter. It will be considered later.

In the vehicle, the antenna has to feed three receivers. This will be considered next. The noise figure to be expected if three receiver inputs (not including the bandpass filter) are connected to the generator, will be calculated first.

The equivalent input circuit for one receiver input is shown in Figure A-5. The noise of the generator source impedance R_1 can be represented by a noise voltage $\sqrt{4KTBR_1}$ in series with R_1 . The total noise of the receiver input is represented by \bar{V}_n

[including: (1) thermal noise, contributed by input resistance R_2 ; (2) shot noise, associated with the emitter-base junction; (3) partition noise, associated with the random distribution of the current between collector and base, (4) semi-conductor noise, and (5) the contribution of the mixer according to Equation (A-1)]. Since the major part of the transistor noise is generated inside the transistor³, the noise source \bar{V}_n can be treated the same way as that of a tube associated with the equivalent noise resistor R_{eq} . The signal output voltage is

$$V_{out} = V_S \frac{R_2}{R_1 + R_2} \quad (A-4)$$

The total noise voltage at the output is:

$$\bar{V}_{n(\text{total})} = \sqrt{4KTBR_1 \left(\frac{R_2}{R_1 + R_2} \right)^2 + \bar{V}_n^2} \quad (A-5)$$

³ A.W. Lo, R.O. Endres, J. Zawels, F.D. Waldhouer, C.C. Cheng, "Transistor Electronics," Prentice-Hall, Inc.

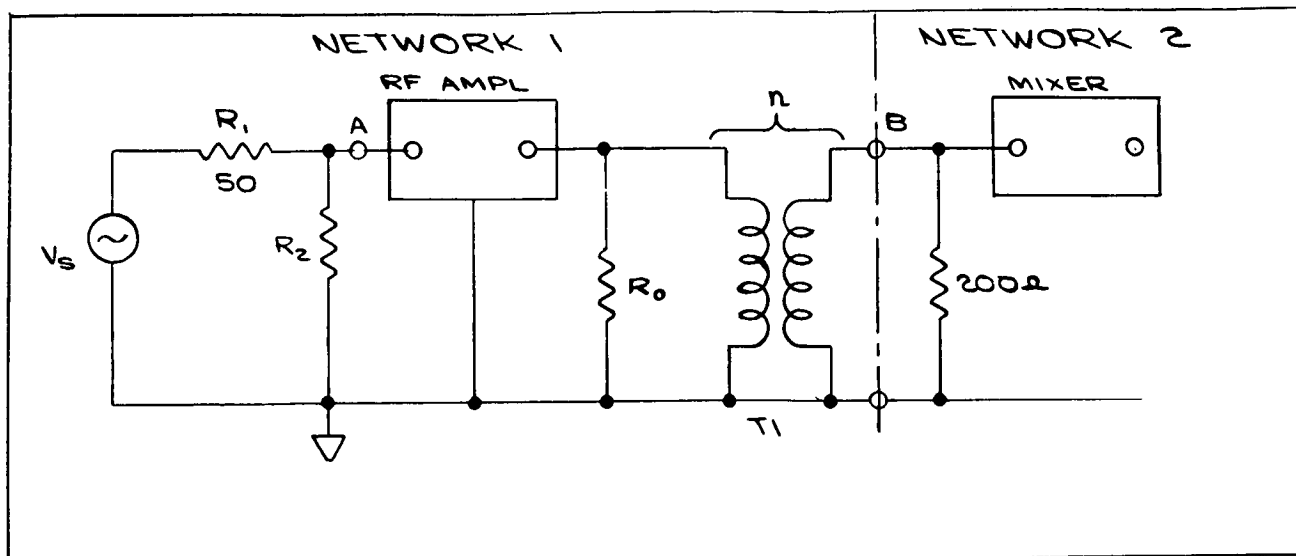


Figure A-4. Amplifier Gain-Evaluation Circuit

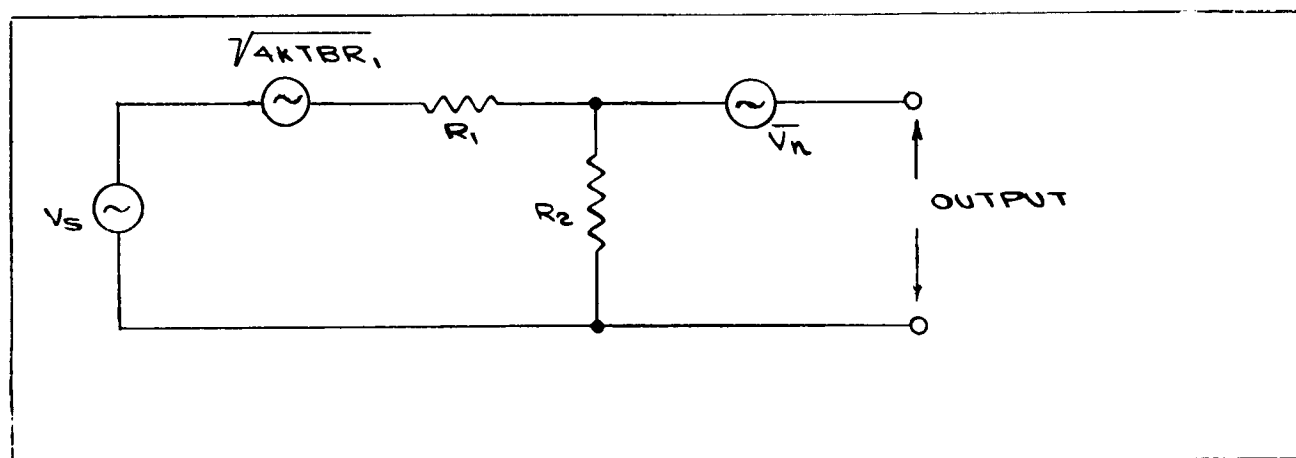


Figure A-5. Equivalent Input Circuit for One Receiver

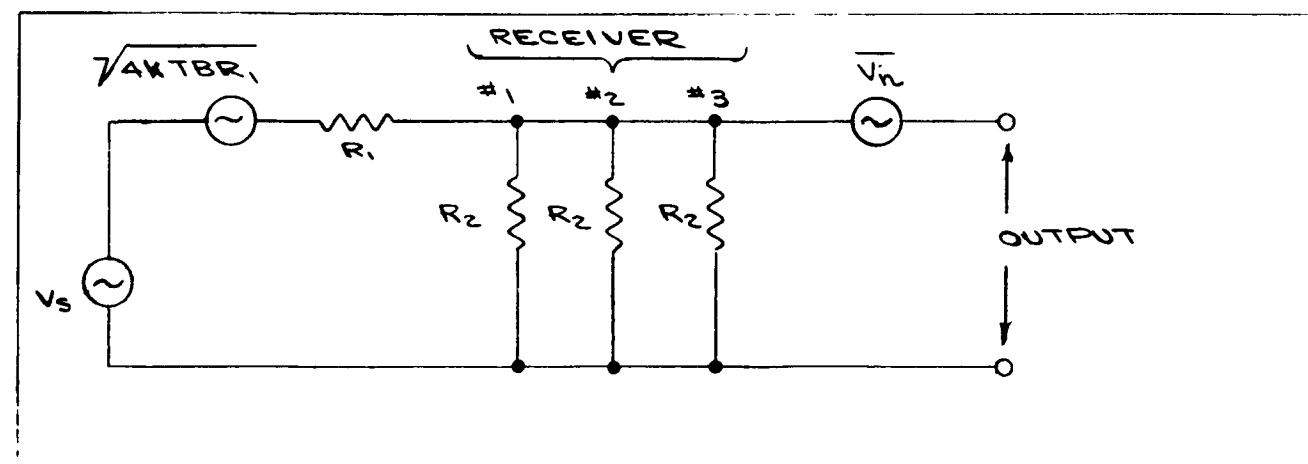


Figure A-6. Equivalent Input Circuit for Three Receivers

Equating Equations (A-4) and (A-5) yields:

$$\frac{V_S^2}{4KTBR_1} = 1 + \frac{\bar{V}_n^2}{4KTBR_1} \left(\frac{R_1 + R_2}{R_2} \right)^2 = 1 + \alpha \frac{(1 + x)^2}{x} \quad (\text{A-6})$$

Where:

$$x = \frac{R_2}{R_1}, \text{ and } \alpha = \frac{\bar{V}_n^2}{4KTBR_2} \quad (\text{A-7})$$

Figure A-6 shows the equivalent circuit from three receiver inputs connected to the generator.

For the signal:

$$V_{S(\text{out})} = \frac{\frac{R_2}{3}}{R_1 + \frac{R_2}{3}} = V_S \left(\frac{R_2}{3R_1 + R_2} \right) \quad (\text{A-7})$$

For the noise:

$$V_{n(\text{total})} \approx \sqrt{4KTBR_1 \left(\frac{\frac{R_2}{3}}{R_1 + \frac{R_2}{3}} \right) + \bar{V}_n^2} \quad (\text{A-8})$$

NOTE: Referring to receiver No. 3 as the one for which the noise figure is to be determined, Equation (8) does not take the noise contribution of R_2 for receiver No. 1 and No. 2 into account. However, the error due to this approximation is negligible, since as mentioned before, most of the transistor noise is generated inside the transistor. (This

APPENDIX A

was confirmed experimentally when the output noise level in receiver No. 3 was found not to vary whether or not receiver No. 1 and No. 2 were connected.)

Equating Equations (A-7) and (A-8) yields:

$$\frac{V_n^2}{4KTBR_1} = 1 + \frac{\bar{V}_n^2}{4KTBR_1} \left(\frac{3R_1 + R_2}{R_2} \right)^2 = 1 + \alpha \frac{(3+x)^2}{x} \quad (\text{A-9})$$

Knowing the noise figure of one receiver, the noise figure of any one of the three receivers connected to the same generator can be readily determined.

From Equation (A-6) with $x = 1$ (minimum noise figure):

$$1 + 4\alpha = 6.5 \text{ (or 8 db)}$$

or

$$4\alpha = 5.5$$

$$\alpha = 1.37$$

From Equation (A-9), with $x = 3$ (minimum noise figure):

$$\frac{V_S^2}{4KTBR_1} = (1 + 1.37) 12 = 17.5 \text{ (or 12.5 db)}$$

Experimentally, a noise figure of 13 db was obtained.

EFFECT OF THE BANDPASS FILTER ON NF

The bandpass filter in Figure A-1 serves to reject unwanted signals outside the pass band which otherwise would reach the r-f input stages and possibly cause cross-modulation. This filter has losses, the effect of which on the noise figure is now to be determined (see Figure A-7). The primary losses of the transformer T are concentrated in R_{T1} , the secondary losses in R_{T2} .

With

$$R_1 = \frac{R_1 R_{T1}}{R_1 + R_{T1}}$$

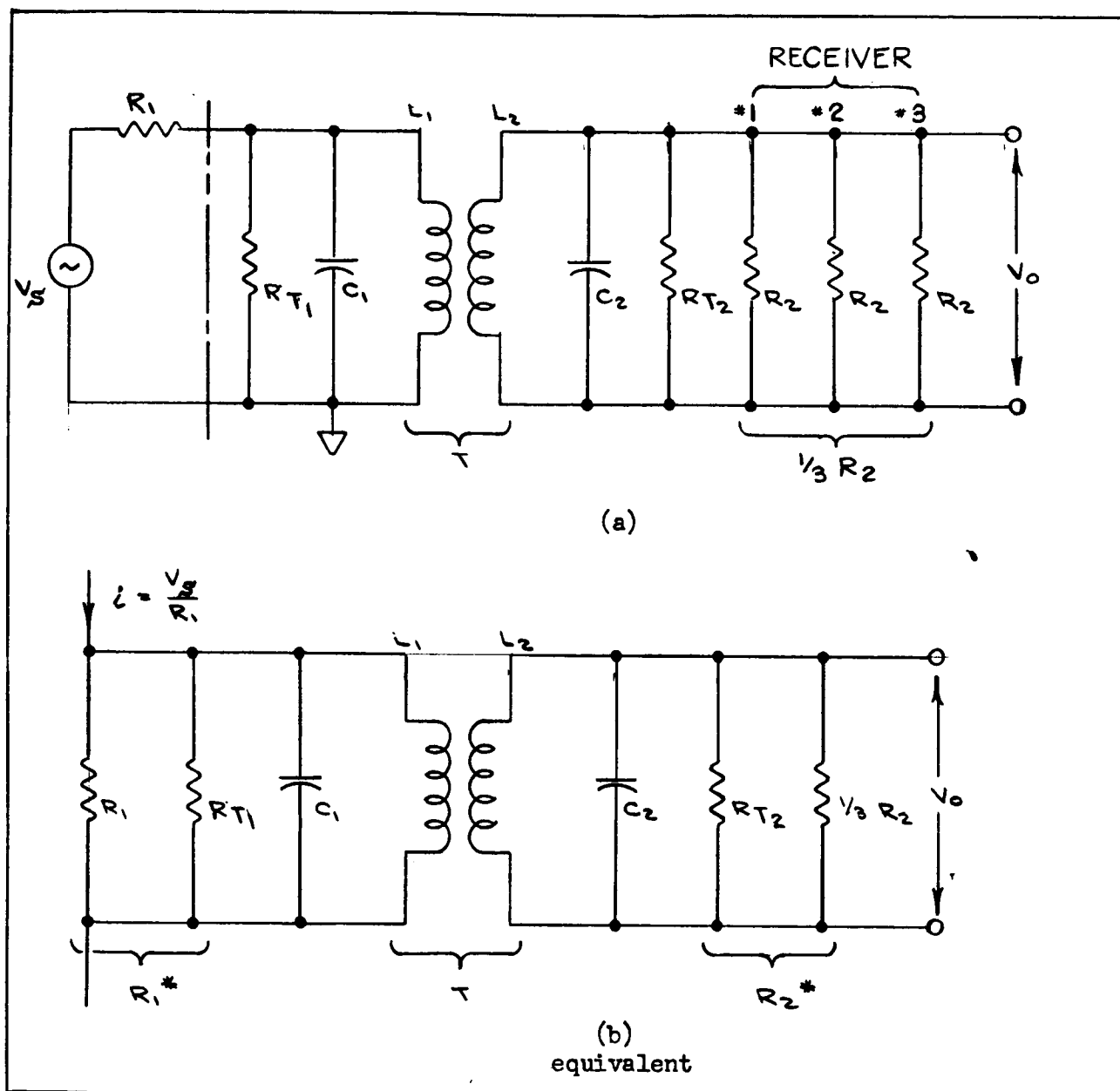


Figure A-7. Circuit for Filter Noise Figure Determination

APPENDIX A

and

$$R_2 = \frac{R_1 R_{T_1}}{R_2 + R_{T_2}}$$

the transfer impedance for maximum power transfer is:

$$Z_{T(\max)} = \frac{1}{2} \sqrt{R_1 R_2}$$

The output voltage V_o :

$$V_{o(\max)} = i Z_{T(\max)} = \frac{V'_S}{R_1} \left(\frac{1}{2} \sqrt{R_1 R_2} \right)$$

The output power, dissipated in each of the three receiver's input impedances R_2 then is:

$$P_{\max} = \frac{V_{o(\max)}^2}{R_2} = \frac{V_S^2}{4R_1^2} \left(\frac{R_1 R_{T_1}}{R_1 + R_{T_1}} \right) \left(\frac{R_{T_2} \frac{R_2}{3}}{R_{T_2} + \frac{R_2}{3}} \right) \left(\frac{1}{R_2} \right)$$

$$P_{\max} = \frac{1}{3} \left(\frac{V_S^2}{4R_1} \right) \left(\frac{R_{T_1}}{R_1 + R_{T_1}} \right) \left(\frac{3R_{T_2}}{3R_{T_2} + R_2} \right) \quad (\text{A-10})$$

when

$$Q_1 = \omega_o R_1 C_1$$

$$Q_1 = \omega_o \frac{R_1 R_{T_1}}{R_1 + R_{T_1}} C_1$$

$$Q_{T_1} = \omega_o R_{T_1} C_1$$

Therefore:

$$\frac{R_{T_1}}{R_1 + R_{T_1}} = 1 - \frac{Q_1}{Q_{T_1}}$$

$$Q_2 = \omega_o C_2 \frac{R_{T_2} \times 3R_2}{R_{T_2} + 3R_2}$$

$$Q_{T_2} = \omega_o C_2 R_{T_2}$$

$$\frac{R_{T_2}}{R_{T_2} + 3R_2} = \left(1 - \frac{Q_2}{Q_{T_2}}\right)$$

Thus:

$$P_{\max} = \frac{1}{3} \frac{V_S^2}{4R_1} \left(1 - \frac{Q_1}{Q_{T_1}}\right) \left(1 - \frac{Q_2}{Q_{T_2}}\right) \quad (\text{A-11})$$

Equation (A-11) shows that the maximum power delivered from the source to each of the three receivers is equal to one-third of the available signal power multiplied by the factor

$$\left(1 - \frac{Q_1}{Q_{T_1}}\right) \left(1 - \frac{Q_2}{Q_{T_2}}\right)$$

This factor takes care of the losses in the transformer. (For the conditions $Q_{T_1} = \infty$ and $Q_{T_2} = \infty$, this factor is unity.)

Assuming now a bandwidth B of 10 Mc with a center frequency f_o of 150 Mc

$$Q_1 = Q_2 = \frac{f_o}{B} \sqrt{2} = 21.3$$

if

$$Q_{T_1} = Q_{T_2} = 100,$$

then

$$\left(1 - \frac{21.3}{100}\right)^2 = 0.62$$

The power delivered to each of the three receivers, therefore, will be reduced by a factor of 0.62, corresponding to an increase in the noise figure of $10 \log \frac{1}{0.62} = 2$ db.

APPENDIX A

The measured NF with the bandpass filter connected between the antenna and the receiver input was 15 db.

An alternate method of feeding three receivers from the same generator through three separate bandpass filters is shown in Figure A-8. Assuming the three networks are identical in every respect, and splitting the generator impedance R_1 into three resistors $3R_1$ (in parallel), it can readily be seen that the current i divides into three equal parts, one being $i/3 = \frac{VS}{3R_1}$. In other words, there will be no interaction between the three networks. Under this assumption, any one of the three inputs can be considered separately (i.e., independent of the two other ones) as depicted in Figure A-9.

Maximum power dissipated in R_2' :

$$P_{\max} = \frac{V_o^2}{R_2} = \frac{V_S^2}{9R_1^2} \cdot \frac{1}{4} \cdot \frac{R_{T_1} \times 3R_1}{R_{T_1} + 3R_1} \cdot \frac{R_2 \times R_{T_2}}{R_2 + R_{T_2}} \cdot \frac{1}{R_2}$$

$$P_{\max} = \frac{1}{3} \cdot \frac{V_S^2}{4R_1} \cdot \frac{R_{T_1}}{R_{T_1} + 3R_1} \times \frac{R_{T_2}}{R_2 + R_{T_2}} \quad (\text{A-12})$$

With

$$Q_1 = \omega_o R_1 C_1 = \omega_o \frac{3R_1 R_{T_1}}{3R_1 + R_{T_1}}$$

$$Q_{T_1} = \omega_o R_{T_1} C_1$$

$$1 - \frac{Q_1}{Q_{T_1}} = \frac{R_{T_1}}{3R_1 + R_{T_1}}$$

and

$$Q_2 = \omega_o R_2 C_2 = \omega_o \frac{R_2 R_{T_2}}{R_2 + R_{T_2}} C_2$$

$$Q_{T_2} = \omega_o R_{T_2} C_2$$

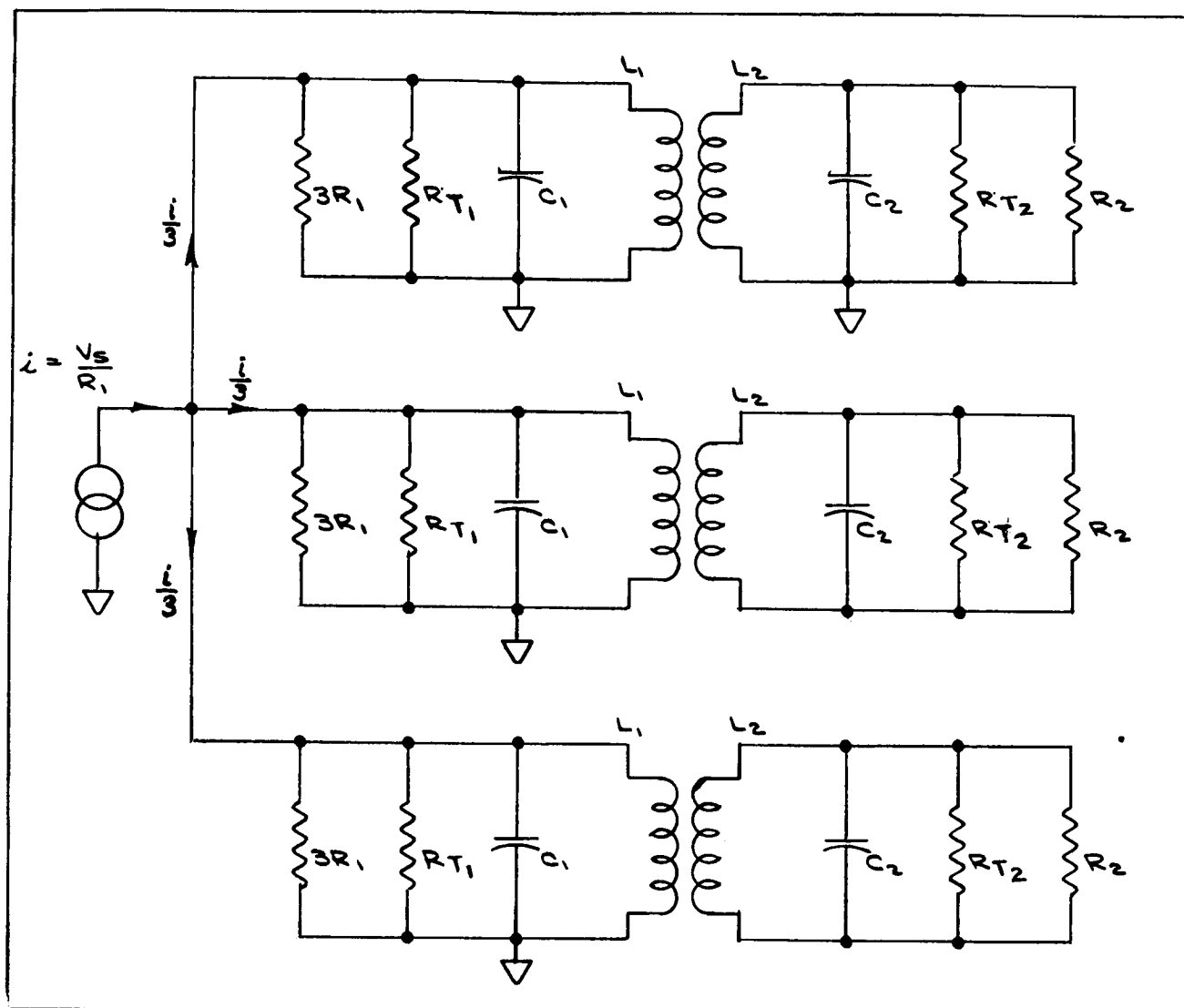


Figure A-8. Alternate Method of Feeding Three Receivers with One Generator

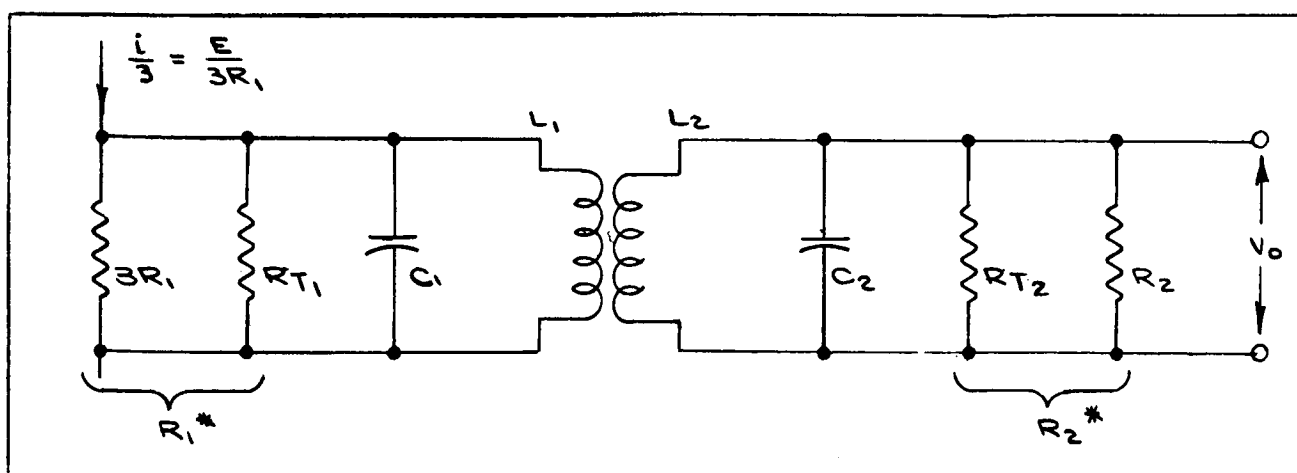


Figure A-9. Equivalent Independent Input Circuit

$$1 - \frac{Q_2}{Q_{T_2}} = \frac{R_{T_2}}{R_2 + R_{T_2}}$$

Therefore:

$$P_{\max} = \frac{1}{3} \frac{V_S^2}{4R_1} \left(1 - \frac{Q_1}{Q_{T_1}} \right) \left(1 - \frac{Q_2}{Q_{T_2}} \right) \quad (\text{A-13})$$

A comparison with Equation (A-12) shows that the circuits of Figure A-7 and Figure A-8 are identical, assuming the same over-all bandwidth and the same Q_T in the transformer. The disadvantage of the circuit of Figure A-8 is the fact that creating three networks completely identical (which is necessary to avoid interaction between them) is very difficult. In case one of the three filters is completely detuned (either due to misadjustment or damage to any of the components), the input impedance approaches zero as Ω reaches ∞ . In this case, the total current i (i.e., $\frac{V_S}{R_1}$) flows into the short circuit, which - being a parallel network - also shorts out the other two inputs. Thus the circuit of Figure A-8 has no advantage over the one of Figure A-7, but does offer difficulties in the requirement for critical alignment.

SELECTIVITY

The attenuation of a significant frequency outside the passband may be calculated as:

$$\left[1 + \left(\frac{\Omega}{\sqrt{2}} \right)^4 \right]^{-\frac{1}{2}} = \left[1 + \left(\frac{\left[\frac{\omega}{\omega_o} - \frac{\omega_o}{\omega} \right] Q}{\sqrt{2}} \right)^4 \right]^{-\frac{1}{2}}$$

With

$$Q = 21.3 \text{ (} B = 10 \text{ Mc), and } f_o = \frac{\omega_o}{2\pi} = 150 \text{ Mc} =$$

$$|\sigma| = \frac{1}{99}, \text{ or } 39.9 \text{ db}$$

The actually measured attenuation was about 40 db.

SIGNAL-TO-NOISE RATIO UNDER OPERATING CONDITIONS

For a 2000 mile range (3.2×10^6 meters) between the satellite and the ground station, 200 watts of transmitter power, -3 db receiver antenna gain, 10 db transmitter-antenna gain, and a wavelength of about 2 meters, the available power from the receiver antenna is:

$$\frac{V_S^2}{4R} = P_r = \frac{P_t \times G_r \times G_t \times \lambda^2}{(4\pi R)^2} = \frac{200 \times 0.5 \times 10 \times 4}{16 \times 9.8 \times 10^{13}} = 2.55 \times 10^{-12} \text{ watts}$$

With $R = 50$ ohms (antenna impedance):

$$V_S = 2 \sqrt{(2.55 \times 10^{-12}) (50)} = 22.6 \mu v$$

With a noise figure of 15 db (a power ratio of 32) and a receiver bandwidth of 100 cps, the generator voltage, V_S' , required for a signal-to-noise ratio of 1:1 is (according to the definition of noise figure):

$$V_S' = \sqrt{F \times 4KTBR} = \sqrt{32 \times (4) (4 \times 10^{-21}) (100) (50)} = 0.05 \mu v$$

The signal-to-noise ratio under the above circumstances then will be

$$\frac{V_S}{V_S'} = \frac{22.6}{0.05} = 450, \text{ or } 53 \text{ db}$$

NOTE: This figure assumes 100 percent modulation of the carrier, and a second detector which does not change the signal-to-noise ratio in the audio band.

The actual circuit of the receiver input is shown in Figure A-10. Note that in order to get technically realizable values of the components in the bandpass filter, the source and the load were coupled through a capacitive transforming network of the form shown in Figure A-11, such that the required bandwidth was obtained. With $L_1 = L_2 = 0.1 \mu h$; $C_1 = C_2 = 11.0 \mu \mu f$;

and

$$\left. \begin{aligned} C_1 &= \frac{C_1' C_1''}{C_1' + C_1''} \\ C_2 &= \frac{C_2' C_2''}{C_2' + C_2''} \end{aligned} \right\} \quad (A-14)$$

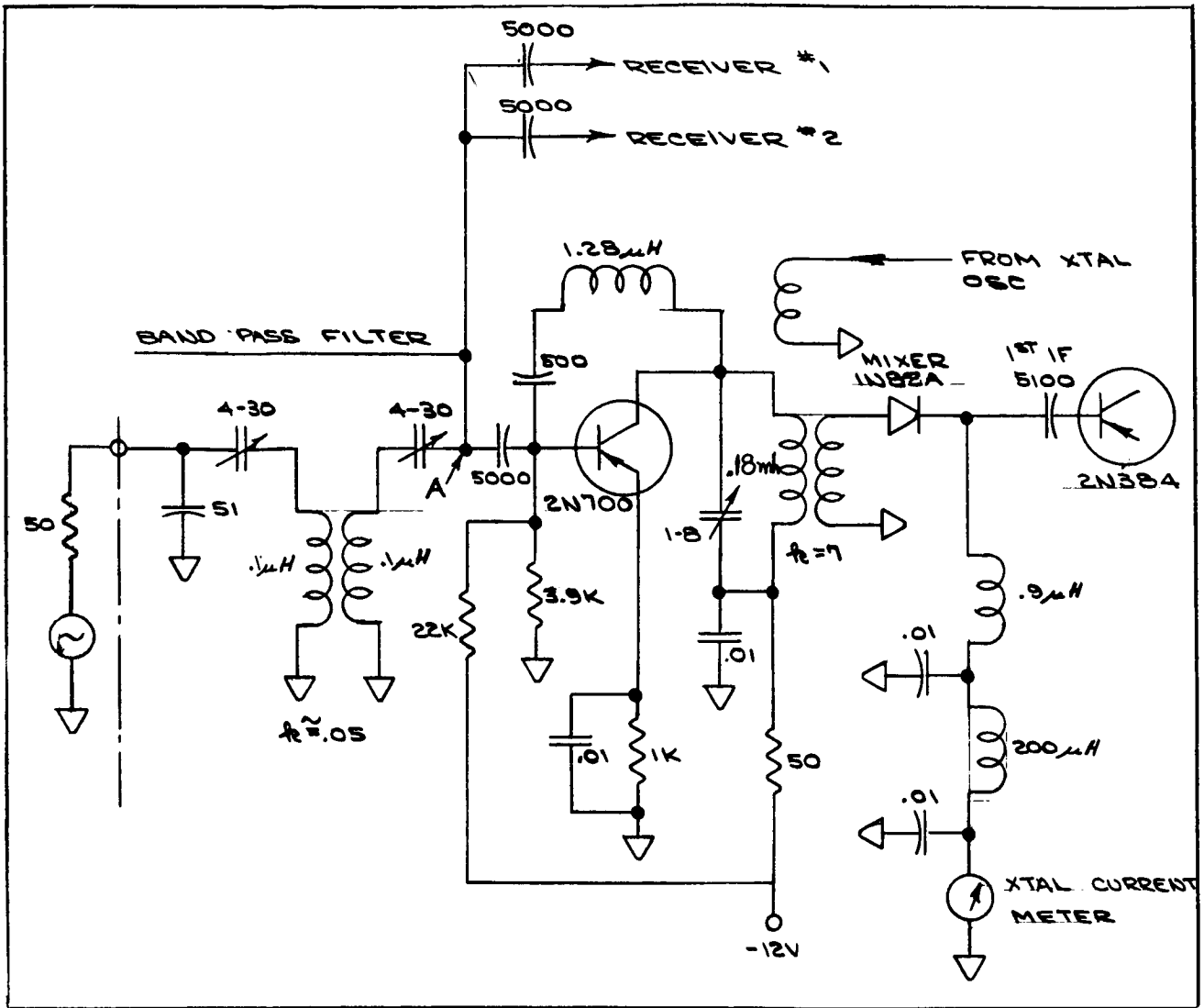


Figure A-10. Actual Receiver Input Circuit

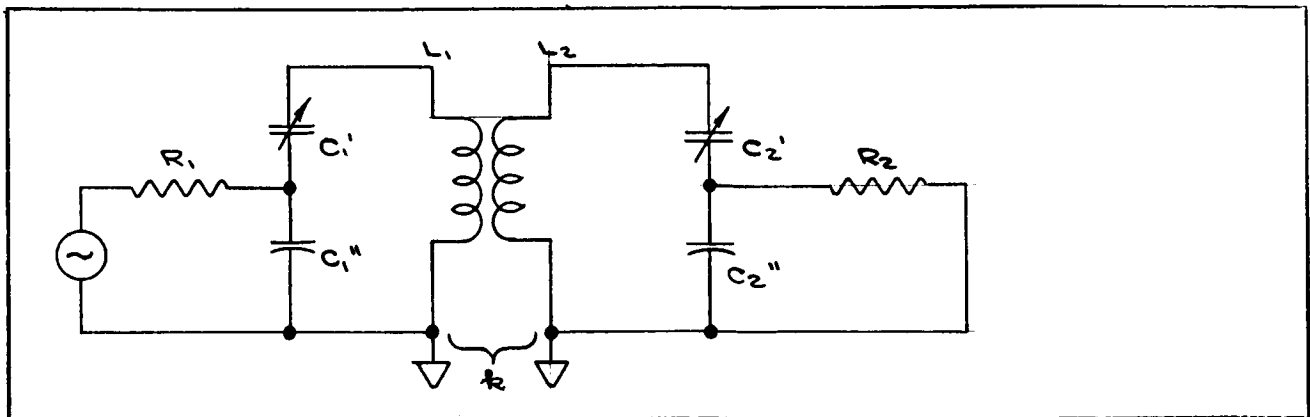


Figure A-11. Capacitive Transforming Network

The capacitors C_1' , C_1'' , C_2' and C_2'' function as a transformer with the turns ratio:

$$\left. \begin{aligned} n_1 &= \frac{C_1'}{C_1' + C_1''}, \text{ or} \\ n_2 &= \frac{C_1'}{C_2' + C_2''} \end{aligned} \right\} \quad (\text{A-15})$$

for

$$\left(\frac{1}{\omega C_1''} \right)^2 < < R_1^2, \text{ and } \left(\frac{1}{\omega C_2''} \right)^2 < < R_2^2$$

Combining Equations A-14 and A-15 yields:

$$\left. \begin{aligned} C_1'' &= \frac{C_1}{n_1} ; C_1' = \frac{C_1}{1 - n_1} \\ C_2'' &= \frac{C_2}{n_2} ; C_2' = \frac{C_2}{1 - n_2} \end{aligned} \right\} \quad (\text{A-16})$$

n_1 and n_2 are determined by the Q necessary to obtain the required bandwidth for:
 $Q_1 = Q_2 = 21.3$ ($B = 10$ Mc at $f_o = 150$ Mc)

$$R_1' = \frac{R_1}{n_1^2} = \omega_o L_1 Q_1 = 2000 \text{ ohms}$$

$$n_1 = \sqrt{\frac{R_1}{2000}} = \sqrt{\frac{50}{2000}} \approx \frac{1}{6.35} = n_2$$

Assuming, for simplicity, $R_1 = R_2$

Then

$$C_1' = C_2' = \frac{11}{1 - \frac{1}{6.35}} = 13.1 \mu\mu f$$

$$C_1'' = C_2'' = 11 \times 6.35 = 70 \mu\mu f$$

Hence for critical coupling $kQ = 1$,

$$k = \frac{1}{20} = 0.047$$

Then, the matching of R_1 and R_2 is automatically taken care of by critical coupling.

The connections from the distribution point A to the three receiver inputs can be accomplished by three half-wavelengths coaxial lines, which act like a transformer with a 1:1 turn ratio. (Experimentally, it was done with RG-59A/U coaxial cable. The three half-wavelength lines were practically loss free.)

APPENDIX B

DERIVATION OF THE SYSTEM EQUATIONS FOR THE PHASE MONOPULSE TRACKING SYSTEM

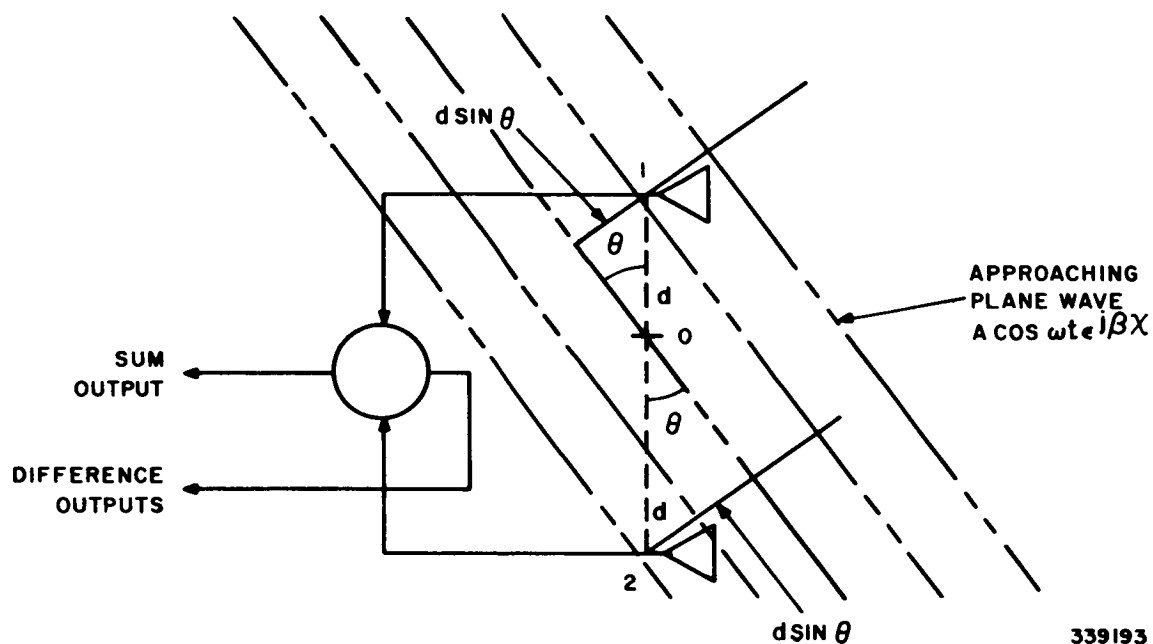


Figure B-1. Monopulse Tracking System, Functional Diagram

Figure B-1. Monopulse Tracking System, Functional Diagram, relates to the following derivation.

Consider the origin (o) to be at 0; then the wave at the origin is simply $\cos \omega t e^{j\beta 0} = \cos \omega t$. Therefore the wave at 1 leads that at 0 by a distance $(d \sin \theta)$, and the wave at 1 may be written as

$$W_1 = A \cos \omega t e^{j\beta(d \sin \theta)}$$

Similarly the wave at 2 lags that at 0 by $(d \sin \theta)$ so that it may be written:

$$W_2 = A \cos \omega t e^{-j\beta(d \sin \theta)}$$

APPENDIX B

The sum output is

$$W_1 + W_2 = \left(e^{j\beta(d \sin \theta)} + e^{-j\beta(d \sin \theta)} \right) A \cos \omega t$$

and the difference output is

$$W_1 - W_2 = \left(e^{j\beta(d \sin \theta)} - e^{-j\beta(d \sin \theta)} \right) A \cos \omega t$$

Simplified, these expressions are

$$W_1 + W_2 = 2 \cos \omega t \cos [\beta d \sin \theta]$$

$$W_1 - W_2 = 2jA \cos \omega t \sin [\beta d \sin \theta] = 2A \sin \omega t \sin [\beta d \sin \theta]$$

Assuming small angles, which is a good assumption since the antenna is fast enough so that the error never gets large:

$$W_1 + W_2 \cong 2A \cos \omega t; \quad \beta d \sin \theta \rightarrow 0 \quad \text{as} \quad \theta \rightarrow 0$$

$$W_1 - W_2 \cong 2A \sin \omega t (\beta d \theta); \quad \theta \rightarrow 0$$

If $W_1 - W_2$ is now phase shifted by 90° and put into a product detector with

$\omega_1 + \omega_2$:

$$(\omega_1 - \omega_2)(\omega_1 + \omega_2) = 4A^2 \beta d \theta \cos^2 \omega t$$

Since a good AGC can be used, A will be a constant and $4A^2 \beta d$ can be lumped into a single constant K .

Therefore:

$$(W_1 - W_2)(W_1 + W_2) = K \theta \cos^2 \omega t = \frac{K \theta}{2} (1 + \cos 2 \omega t)$$

If a low pass filter is now used, an error signal is obtained:

$$E = \frac{K \theta}{2}$$

The d-c error is then proportional to the size of the angle θ and changes in sign as θ does.

APPENDIX C

RCA-TIROS TEST SPECIFICATIONS AND INSTRUCTIONS

PART I. TIROS SATELLITE ACCEPTANCE TESTS (SP-T2-200)

PURPOSE

This document lists the tests (and the order of application) which the TIROS satellite must pass in order to be "accepted" by the customer.

ACCEPTANCE TESTS

1. Complete standard performance evaluation test as per SP-T1-200. (Part II of this Appendix)
2. Spin, as detailed in TSP-T1-100B Paragraph 2.3.3. (Appendix C of this report), (The test is the same for both the prototype and flight units).
3. Despin. This test is required only for the prototype.
4. Complete standard performance evaluation test as per SP-T1-200.
5. Vibration per TSP 100B Paragraph 2.3.1. (Prototype) or 2.4.1 (Flight) vehicle. The equipment will not be powered except for those items to be operated during launch. Those items will not be monitored during this test but performance measurements will be taken before and after vibration.

The units to be powered are:

Beacon Transmitters, Command Receivers, Clocks and Oscillators.

6. Complete standard performance evaluation as per SP-T1-200.
7. Acceleration test will be performed per TSP-T1-100B Paragraph 2.3.2 (Prototype) or Paragraph 2.4.2 (Flight) vehicle. Units to be operated during launch will be powered and monitored during this test. After acceleration, the entire vehicle will be physically inspected (externally). This test will be performed at Belocks Labs.
8. Complete standard performance-evaluation test as per SP-T1-200.
9. Temperature. Both prototype and flight vehicles will be operated under combined thermal-vacuum environment. Testing will start when pressure is no greater than 5×10^{-5} mm Hg. The pressure may be lowered or raised as unit is cooled or heated but will not be allowed to rise above 1×10^{-4} mm Hg

APPENDIX C

[REDACTED]

at the highest temperature. Base plate temperature will be measured at various locations, but one point will be picked as the control point to determine stabilization. This point will be the coldest or hottest point registered (depending upon the part of the cycle being considered).

Stabilization is defined as a period of two hours with essentially no change in temperature ($\pm 1^\circ \text{C}$) on the control point. Since these tests are performed on an essentially complete vehicle (less antennas), it will not be feasible to monitor internal temperatures as originally planned, except by monitoring the output of the temperature sensors. Power will be supplied from an external source since solar cell charging is not feasible.

During these tests the vehicle will be interrogated every 2 hours. During interrogation the following functions will be performed alternately on TV Camera chains 1 and 2:

1. Direct camera
2. Playback tape
3. Set clock
4. Start clock

In addition, at least once at each temperature, the beacon kill and start function will be programmed.

PART II. INSTRUCTIONS FOR "STANDARD" PERFORMANCE-EVALUATION TESTS (TSP-T1-200)

PURPOSE

These tests are designed to give a measure of satellite performance. The results of these tests, when compared with previous tests, will indicate any change in performance of the satellite's components as a result of environmental stress or aging. They will also serve as a method of comparison of the performance of different payload assemblies. The testing sequence is not intended to prove compatibility between the payload and the associated ground equipment, since this has already been thoroughly established during system testing of the T1 and T2 models.

TEST SCHEDULE

This sequence of tests will be performed before and after each environmental condition, and before shipment of a satellite. A record of the test results will accompany each unit for use by the pre-launch activity.

Test I. Command Receiver Sensitivity and Selectivity

1. Throughout this and all other tests make certain all transmitter output cables are terminated either into a receiver (through appropriate attenuation), or into a 50 ohm load.

Connect a monitor receiver to TV transmitter output line, through appropriate attenuation. Adjust a signal generator to the command frequency within ± 1 kc using a frequency counter. Monitor the generator output for several minutes to ensure that the generator has stabilized. Reduce the output level of the generator to zero, and connect to input fixture which replaces the command receiver antenna on top of the satellite. (This fixture includes a 6 db pad to properly terminate the generator line and simulate the antenna source impedance).

Adjust the signal generator output to one microvolt, and modulate it 100% with the DIRECT CAMERA I command tone. Wait 30 seconds. If the TV transmitter does not come on, increase the generator output by 1/2 microvolt and wait 30 seconds. Continue increasing in 1/2 microvolt steps until the transmitter is activated. If the transmitter is activated at one microvolt, reduce the

generator output to zero, and then increase it until the transmitter turns on. Record the generator voltage required to activate the system.

2. Repeat the above sequence, modulating the generator output with the DIRECT CAMERA II command tone.
3. Repeat the sequence, modulating with the PLAYBACK I command tone.
4. Repeat the sequence, modulating with the PLAYBACK II command tone.
5. Remove the modulation, and connect the generator to the frequency counter unit. Check the frequency. If it has drifted more than 4 kc, it is necessary to reset it and repeat the above tests. (4 kc is 10% of the nominal receiver bandwidth).
6. Set the signal generator 10 kc below the command frequency; reduce the output to zero; and repeat the above test. Check the generator frequency for drift; if more than 10%, reset the frequency and repeat the test.
7. Set the signal generator 10 kc above the command frequency; repeat the test; and check for frequency drift. Repeat the test if necessary.

Test II. Transmitter Power Output and Frequency

Since it is not possible to obtain an accurate power output indication with the transmitters connected to the radiating antennas, the assembly of the satellite will be completed without connecting the antennas. Instead, six coaxial leads will be brought out for measurement purposes. Four of these will be fed from the two TV transmitters through the transmitter diplexer and balun assembly. The other two will come directly from the beacon transmitters. It is necessary to isolate the beacon outputs from the diplexer assembly for these measurements, since the beacon transmitters are on all the time and the output would disturb power readings on the TV transmitters as well as on each beacon individually. Make the following tests:

1. Terminate all coaxial output lines with 50 ohm loads, except the output from the higher-frequency beacon transmitter. Terminate the coax from the higher frequency beacon transmitter with the calometric watt meter. Close the toggle switch connecting the satellite batteries, and record the power output. Connect an appropriate frequency counter unit, and read the transmitter frequency. Disconnect the satellite batteries (i.e., open the toggle switch).
2. Repeat the above procedure for the lower frequency beacon. Record the data. Repeat the above test procedure for TV transmitter No. 1, measuring the power, respectively, to the N, S, E, and W radiating elements of the antenna. (Program DIRECT CAMERA 1 to turn on the transmitter).
3. Repeat the above test for N, S, E, and W antenna power from TV transmitter No. 2.

Make sure all coaxial lines are terminated during the time the satellite batteries are connected.

Test III. Evaluation of Control Tone Filters, Control Tone Detectors, Power Control Relays, Cameras, Video Subcarrier Oscillators, Direct Mode Camera Shutter and Synchronizing Circuits

Before this test is started, calibrate all ground terminal equipment with the station calibrator, to insure accurate readings. Connect the signal generator output to the receiver input fixture, and adjust its output level to 50 microvolts. Connect the charger to the satellite battery. Turn on the Satellite. Connect a calibrated receiver to the output of the one TV transmitter diplexer line through 100 db attenuation. Connect the telemetry receivers to the beacon output through appropriate attenuators. Place the standard illuminated test patterns in front of the camera lenses. Connect all ground receiver outputs to appropriate ground station terminal equipment.

1. Program the equipment for DIRECT CAMERA I and II and note the time the command tone comes on. Record the elapsed time before the first TV transmitter carrier goes on, and check for telemetry output on both telemetry receivers.
2. Remove and attach telemetry record to test record with appropriate notation.
3. While the cameras are alternating, note and record the following data for each camera system:
 - a. Time interval between pictures when both transmitters are off.
 - b. Amplitude of TV subcarrier out of receivers.
 - c. Amplitude of sync pulses out of TV, FM demodulator.
 - d. Amplitude of video signal out of TV, FM demodulators.
 - e. Picture centering, (record the percent of full picture width off center).
 - f. Frequency of horizontal sync pulses.
4. Make hard copy prints of 10 pictures; attach these to the test record.
5. With the cameras still alternating, cap both TV camera lenses and, note the approximate peak-to-peak value of noise on the synch tips and during the horizontal line as it appears on the ground monitor oscilloscope.
6. Record the peak-to-peak value of horizontal synch pulses out of the FM demodulator; note any unusual appearance of synch pulses, such as droop of pulse, excessively long rise time, etc.
7. Record, in percentage, the amplitude and approximate frequency of any extraneous pulses.

Test IV. Evaluation of Clock Remote Timing, Tape Recorders, and Associated Tone Filters

1. Uncap the TV camera lenses.

APPENDIX C

2. With the equipment connected as in Test II, manually program the satellite for **PLAYBACK I**. When the TV transmitter comes on, send 8970 clock pulses to both clocks. Send the clock start pulse, and note the time it was sent.
3. Discontinue all command signals and wait for the clocks to alarm. This can be detected by the audible click when the clocks "step out".
4. Record the time of clock alarm. The clocks should be in synchronism, this will be indicated by one strong click every two seconds.
5. After about 30 seconds, the tape motors should be heard. Observe and record the time elapsed from clock alarm to tape motor start. The tapes should run about 3 seconds every 30 seconds. Note and record the running time of the tapes and the interval between recordings. After about 10 minutes, cap both camera lenses and allow the cycle to go to completion.
6. Command **PLAYBACK SEQUENCE 1N**, and note the time elapsed before the TV transmitters come on. (To insure exact timing, this function must be programmed with the ground control equipment operating from the master clock).

Since playback lasts only about 90 seconds, the following measurements must be made as rapidly as possible. Record all pictures photographically. Identify and attach them to the test record.

Note and record the following data:

- a. D-C. Position of sync tips on first or second picture.
- b. Amplitude of video subcarrier out of TV receiver.
- c. Horizontal sync frequency.
- d. Approximate time between pictures.

Since pictures are played back in reverse order, first pictures will be the ones with the camera lense capped. Record:

- a. Peak-to-peak sync amplitude.
- b. Peak-to-peak noise on sync tip (percentage of sync).
- c. Peak-to-peak noise on horizontal line (percent of sync).

When pictures start with the lens uncapped, note and record:

- a. Sync amplitude
- b. Video amplitude
- c. D-C level of sync tips
- d. D-C level of sync near end of playback.

Allow the cycle to go to completion and the transmitters to go off. Repeat the above sequence, commanding **PLAYBACK SEQUENCE 2N** instead of 1N.

Test V. Sun Sensors, Horizon Scanner, Spin-Up Rocket, and Beacon Killer Command Functions

Program either camera for direct pictures at 10 second intervals. Position a 1000 watt studio lamp in front of sun angle cell No. 1. Place an opaque sheet (e.g., cardboard) between the lamp and the sensor. Connect an oscilloscope to the output of the 10 kc filter in the ground station equipment.

1. Wait for the 2-second interruption of the control tone from the ground programming equipment. Approximately one second after the tone returns, briefly remove the opaque sheet and expose the cell to the spot light. (The time the cell is exposed is not critical since only the leading edge of the resultant pulse is used to trigger the pulse output. About one second should be satisfactory.)
2. Note and record the amplitude and duration of the 10 kc burst out of the ground station filter. Take a Polaroid photo of the scope pattern.
3. Repeat the above with the other eight sun sensors.
4. Connect a strip heater, and heat it to about 15° C above room temperature. Place the strip about 6 inches from the horizon sensor. Place a black card between the heater and the sensor. Connect an oscilloscope to the audio output of one beacon receiver. Remove the black card for about 3 seconds and replace. Note the amplitude and duration of resulting 3 kc tone bursts out of the receiver.

Repeat ten times at random on-off rates, from 1 to 6 seconds on and 1 to 6 seconds off, and observe the tone bursts for consistency of amplitude, and duration.

5. Connect the oscilloscope to the output of a receiver tuned to the other beacon and repeat the above sequence.
6. With continued picture command, send the spin-up rocket tone manually for 2 seconds. Note the time between initiation of the tone and rocket firing (relay clank). Check for firing voltage on the appropriate pair of rocket-mounting fixtures.
7. Repeat for all rockets.
8. At the termination of the above test, manually send a START CLOCK pulse until beacons go off. Note and record the time between the start of the tone and turn-off. Allow the TV transmitters to go off.
9. Send a DIRECT CAMERA tone manually until the beacons come on again. Record the time between the start of the tone and beacon turn-on.

